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Selected Articles from Soviet Economics Journals in English Translation

SPECIAL ISSUE ON MATHEMATICAL ECONOMICS

P. Zhelezniak: Scientific Conference on the Application of Mathematical Methods in Economic Studies and Planning (Planovoe Khoziaistvo, No. 5, 1960).

A. Aganbegian: Application of Mathematical Methods in Economic Analysis (Planovoe Khoziaistvo, No. 2, 1960).

V. Nemchinov: The Use of Mathematical Methods in Economic Research and Planning (Voprosy Ekonomiki, No. 6, 1960).

V. Shliapentokh: The Use of Mathematical Methods to Determine the Most Rational Pattern of Agricultural Production (Ekonomika Sel'skogo Khoziaistva, No. 7, 1960).

I. Birman: Calculation of an Optimum Scheme of Transportation of Interchangeable Prod-Products (Vesnik Statistiki, No. 5, 1960).

A. Kats: Concerning a Fallacious Concept of Economic Calculations (Voprosy Ekonomiki, No. 9, 1960).

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PROBLEMS OF ECONOMICS

Selected Articles from Soviet Economics Journals in English Translation

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VESTNIK STATISTIKI – JOURNAL OF STATISTICS
VNESHNIAIA TORGOVLIA – FOREIGN TRADE
VOPROSY EKONOMIKI – PROBLEMS OF ECONOMICS
MIROVAIA EKONOMIKA I MEZHDUNARODNYE OTNOSHENIIA – WORLD ECONOMY AND INTERNATIONAL RELATIONS
NAUCHNYE DOKLADY VYSSHEI SHKOLY – EKONOMICHESKIE NAUKI – SCIENTIFIC PAPERS OF HIGHER EDUCATIONAL INSTITUTIONS, ECONOMIC SCIENCES
PLANOVOE KHOZIAISTVO – PLANNED ECONOMY
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MATHEMATICAL ECONOMICS

Planovoe Khoziaistvo, No. 5, 1960

. ZHELEZNIAK:

cientific Conference on the Application of Mathematical ethods in Economic Studies and Planning

A scientific conference on the application of athematical methods in economic studies and planng was held in Moscow in April 1960 under the spices of the USSR Academy of Sciences (Departents of Economics, Philosophy, and Law, and the berian Branch of the Academy). Fifty-six re- rts were read at the plenary meetings of the con- rence's six panels. More than ninety people took rt in the debates.

Academician V. Nemchinov read a paper on the neral problems of applying mathematics in eco- mic studies and planning. He showed the absolute cessity of improving to the utmost the level of alitative analysis of all aspects of planned eco- mic development on the basis of preliminary qual- tive investigations of the laws governing the ogress of the socialist economy. He held that for is purpose it is necessary to create a theory of nning calculations based on the simultaneous use three methods: the balance sheet method, the delling of national economic processes, and the lection of the optimum variant of a program.

Academician Nemchinov indicated the general ections in which the studies of the problems re- ed to the application of mathematical methods in nomic investigations and planning should pro- ed. These include: 1) the working out of a gen- al methodology for preparing and controlling the fillment of optimum national economic plans; 2) preparation of interbranch and interregional ance sheets of production and distribution of the duct in the national economy as a whole and in arate economic regions; 3) the creation of an nomic-mathematical model of the balance sheet expanded reproduction; 4) the solution of prob- ns of optimum programming of the transport sys- n's operations; 5) the application of mathemati- methods to various technical and economic blems; 6) the utilization of mathematical statis- s in economic studies and planning.

n conclusion, Nemchinov outlined certain measures which, once carried into effect, will help to deepen and extend the work of applying mathematical methods and electronic computers in planning and economic practice (training of specialists, expanding the number of laboratories handling economic, mathematical, and planning calculations, establishing an interdepartmental scientific council to deal with these problems, etc.).

Corresponding Member of the USSR Academy of Sciences Bruk spoke of the prospective uses of electronics for controlling the national economy; of the problem of establishing special communications systems for setting up and solving problems with electronic machines; of training engineers, mathematicians and economists for operating these machines; and of elaborating a common computer "language" for programming problems.

Comrade Mstislavskii of the Institute of Economics (USSR Academy of Sciences) surveyed the problems related to the use of balance-sheet systems in the management and planning of the national economy. He posed the problem of developing special mathematical machines for designing models of the social economy in the process of expanded reproduction.

Prof. Novozhilov of Leningrad stressed the necessity of applying methods of higher mathematics in economic calculations for drawing up optimum plans. He dwelt in particular on the problem of measuring inputs and their results, proceeding from the selection of minimum labor inputs for a given volume of production in the socialist economy.

Corresponding Member of the USSR Academy of Sciences Kantorovich analyzed mathematical models for solving problems of optimum planning: a model for current, and one for long-term planning. In using these models in practice he suggested the application of the method of resolving multipliers, which is one of the methods of linear programming. Kantorovich holds that an optimum plan is one that is in conformity with the system of "objectively conditioned estimates" for all types of products and factors of production, which he views as economic indicators of outlays of socially necessary labor.

The reports read at the plenary meeting gave rise to a lively exchange of views. Academician Kolmogorov, Professors Kronrod, Notkin, and others who took part in the discussion, concentrated on the problem of devising an optimum national economic plan and, in particular, elaborating exact economic criteria of the optimum nature of a plan. Among the many speakers Corresponding Members of the USSR Academy of Sciences Markov and Liusternik placed particular emphasis on the outstanding part played by mathematics in the advancement of other sciences and in producing more precise scientific notions and concepts. Comrades Rakovskii (Head of the Computing Center of the USSR State Planning Committee) and Kulev (member of the State Planning Commission of the Russian Federation) also dwelt on the importance of utilizing mathematical methods and electronic computers in the process of planning.

A great deal of attention was devoted to the problems of training mathematicians specializing in planning and economic computations, and of propagating mathematical knowledge among economists. Academician Gnedenko (Ukrainian Academy of Sciences) suggested that special centers for the extensive use of mathematics in factory planning should be established in the bigger industrial plants. Academician Dorodnitsyn raised the important question of setting up special laboratories for the use of mathematical methods in economics at the existing universal computing centers. He went on to stress that at present the prime task is to apply in practice the methods which have already been elaborated, to solve concrete problems and use the results in the work of planning.

A number of comrades who took part in the debates criticized Comrade Kantorovich's views on the economic nature of the "objectively conditioned estimates." Academician Nemchinov specifically criticized Comrade Kantorovich's idea that "objectively conditioned estimates" characterize the outlays of socially necessary labor and that they should be used as a basis for working out the structure of wholesale prices. He pointed out that the "o.c.e.'s" are merely distribution estimates with a narrow rather than universal significance in solving specific problems of determining an optimum variant. Comrade Kats said that the methods proposed by Comrade Kantorovich could be of use only in particular static problems. Comrade Veduta criticized Comrade Kantorovich for his erroneous interpretation of the "o.c.e.'s," adding that their author overestimates the scarcity factor. Comrade Aganbegian voiced the opinion that Comrade Kantorovich mistakenly projects onto the whole national economy the mathematical model of the solution of a specific problem (the load of machine tools, for example), disregarding the qualitative differences between the national economy as a whole an a separate industrial plant. He went on to say tha Comrade Kantorovich attempts to solve problems of dynamics in the development of the national economy without taking account of the basic proportion in reproduction — the relationships between subdivisions I and II, consumption and accumulation, etc.—which is not a valid method. Other speakers came out in support of the views expressed by Comrade Kantorovich, stating that they are valid and that the "o.c.e.'s" have a great practical value

Some mathematicians and electronic machine specialists were critical of Comrade Mstislavskii's report. Prof. Liapunov stated that the propositions set forth by Comrade Mstislavskii lacked concreteness with regard to the construction of mathematical machines for modelling the process of reproduction in the national economy.

Corresponding Member of the USSR Academy o Sciences Khachaturov took part in the debates, outlining the work that is being done in applying mathematical methods in planning at the division capital investment effectiveness of the Institute o Economics (USSR Academy of Sciences). Other speakers included Professor Oparin, who discussed the training of specialists.

Further discussions on applying mathematics i economic studies and planning proceeded in the panels.

The panel on mathematical analysis of expande reproduction and of economic models heard the r port of Professor Boiarskii on differential equations of expanded reproduction; the report of Comrades Pliukhin and Nazarova on chain interrelations in expanded reproduction; Comrades Mikhalevskii, Gorkov, and Veduta on mathematical methods of estimating the economic effectiveness of capital investments; Comrade Novozhilov on criticism of mathematical models of the national economy in bourgeois political economy; Comrad Trigubenko on dynamic programming; and Comrade Konius on the mathematical analysis of the organic structure of production costs.

Academician Kolmogorov jointed in the debates to criticize Comrades Pliukhin and Nazarova for their superficial attempt to mechanically apply th formulas for nuclear chain reaction to the proces of expanded reproduction.

In the panel on interbranch balance sheets of production and distribution of the product in the n tional economy Academician Nemchinov read a

aper on theoretical problems related to inter-
ranch and interregional balance sheets. Profes-
ors Efimov and Berri outlined in their report the
ork done by the Institute of Economic Research of
e State Planning Committee in working out an in-
rbranch balance sheet of production relations.*
omrade Eidel'man (Central Statistical Administra-
on) read a paper on the calculation of the 1959
terbranch balance sheet for the Soviet economy
ade by the Central Statistical Administration and
e State Planning Committee of the USSR. The
ssociates of the laboratory for applied statistical
d mathematical methods in economics (under the
berian Branch of the Academy of Sciences) sur-
eyed various aspects of the interbranch balance
eet of production and distribution of the product
an administrative economic region; then they
mmarized the experience gained in this field by
eir laboratory. Other reports dealt with the na-
re of the coefficients of full costs and their spe-
fic features; with the static and dynamic patterns
material balance sheets in the national economy;
ith models of interbranch balance sheets; with
near matrixes as models of reproduction. Those
o took part in the debate in this panel agreed that
was necessary to use mathematics and electronic
mputers in working out interbranch balance
eets. They also discussed some practical prob-
ms in the designing of such balance sheets.

Eight reports were submitted to the panel on
near programming, dealing mainly with mathemat-
al methods of solving the problems of optimum
riants.

In the panel on the application of mathematical
ethods in planning and operating the transport sys-
m most of the reports were based on factual ma-
rial summarizing the work done in this field by
veral organizations, including the Institute of
mposite Transport Problems, the Computing Cen-
r of the USSR Academy of Sciences, the Acad-
ny's Institute of Electronic Control Machines.

In the panel on the application of mathematical
ethods in technical and economic calculations the
ports dealt with the use of mathematics in organ-
ing and planning the work of industrial plants,
th methods of ascertaining the level of specializa-
n and the geographical distribution of metal-
rking plants, methods of economical cutting of
aterials, etc.

There was a very interesting report on practical
ethods of studying operations in agricultural eco-
mics.

A report entitled "Statistics and the Application of Mathematical Methods in Economic Studies" was read to the panel on mathematical statistics. A number of reports dealt with the problems of applying correlation methods in analyzing production costs, labor productivity, and other technical and economic indicators. Other questions that came under review included the analytical method of studying the consumption-income relation, statistical methods of determining the average price of manufactured articles, and methods of modeling indicators of production growth.

Every panel passed decisions on the problems under discussion. These decisions recommended extending the application of mathematical methods in economic studies and planning in each particular field.

The concluding plenary meeting discussed a program for coordinating the work on applied mathematical methods in economic studies and planning. The program was presented on behalf of the steering committee by Comrade Belkin (Institute of Electronic Control Machines of the USSR Academy of Sciences). This program provides for applying mathematical methods in working out interbranch balance sheets of production and distribution of the product for reporting and planning purposes; in analyzing and planning interregional economic ties; in tabulating labor resources; in calculating real social production costs for the purpose of working out an economically valid system of prices; in elaborating optimum programs of shipments and material and technical supply; in problems of geographical distribution of production capacities; in working out optimum programs of production and utilization of equipment; in designing a model of expanded socialist reproduction; and in a number of other areas. The scientists who took part in the discussion approved this draft program on the whole and added some proposals.

Academician Nesmeianov, President of the USSR Academy of Sciences, presented a brilliant address to the audience at the plenary meeting. He stressed the point that economics must become an exact science making use of mathematics. He added that application of mathematical methods in economic studies and planning was bound to be of great value to the Soviet national economy, amounting in money terms to many billions of rubles. He urged the economists, mathematicians and engineers to join forces to make these billions a reality. On behalf of the Presidium of the Academy of Sciences Comrade Nesmeianov congratulated the assembly on the occasion of the convening of this important scientific conference and stated that the Presidium would be guided by the conference decisions in taking effective steps to promote

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The basic points in these reports are presented
articles published in this issue.

maximum progress in scientific work in this area.

The plenary meeting adopted the basic recommendations on the application of mathematical methods in economic studies and planning and the draft program of coordination. The conference assigned to the steering committee the task of drawing up these documents in their final form and mailing them to the institutions concerned. The recommendations indicate the main fields in which mathematics and electronic computers should be put to practical use in economics and present a number of concrete measures for carrying out this work (establishment of an interdepartmental scientific council, a research institute, a periodical publication, training of more specialists in this field, dissemination of mathematical knowledge among economists, etc.).

In his concluding remarks Academician Nemch nov summed up the work of the conference. It ha greatly contributed to closer cooperation between economists, mathematicians, and engineers in a task of national importance — the utilization of mathematical methods and electronic computers in planning calculations and economic activities.

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Planovoe Khoziaistvo, No. 2, 19

A. AGANBEGIAN:

Application of Mathematical Methods in Economic Analysis*

Karl Marx felt that economics must make extensive use of mathematical methods of analysis. This should especially concern the economics of socialism, which serves as a guide in economic activities and therefore by its very nature is an exact science. The national economic plans can and should determine the trends in the development of our national economy with the same precision as the trajectories of the Soviet space rockets and sputniks were determined. For this purpose modern mathematical methods and electronic computer technique should be widely used in economics and planning. Of course, this can yield favorable results only on the basis of the Marxist-Leninist teachings on the laws of the economic development of society. Mathematical methods can play only an auxiliary role, although quite an important one, in the investigation and planning of economic processes. Therefore, the application of mathematical methods in Marxist-Leninist economic science differs fundamentally from so-called econometrics, which in substance is based on the replacement of the study of economic laws by formal mathematical equations or on the mathematical treatment of the theory of marginal utility.

***

1. Building Mathematical Models for Economic Calculations and the Fields of Their Application

In order to apply mathematics in economic calculations it is necessary to draw up a mathematical model for a given economic process, that is, express the quantitative relations of this process in the form of equations. But since quantitative r lations reflect the qualitative nature of an economic phenomenon, the qualitative analysis must precede the formulation of a mathematical model. Th unity of the qualitative and quantitative aspects o the given economic process is expressed in this mod

One of the main difficulties in building mathem ical models in economics is that our knowledge c one or another process must not be limited to ge eral considerations but must be brought to the point of learning the magnitudes of this process. For instance, in order to build a model of the pro ess of the priority growth of the production of th means of production relative to the production o consumer goods it is insufficient to be aware of the necessity for this priority growth; what must be known is the influence exerted on it by certai factors: the structure of the social product and capital in production, the dynamics of the rate of accumulation, changes in the capital-output rati etc. Therefore, a profound and concrete knowled

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* For purpose of discussion.

economics, brought to the point of perceiving the
agnitudes of the economic process, in the first and
ief condition for the formulation of mathematical
odels in economic analysis and planning. The
athematical model must correctly reflect the
ecific features of the given economic process.
nly on this condition will it lead to correct results.

Economic phenomena are distinguished, as a rule,
their great complexity, and therefore their de-
iled description is made possible with the aid of
mplex models or even systems of such models.
make the model applicable in practice, one must
stract from a number of factors exerting a sec-
dary influence on the tendencies of the given
ocess. Abstraction from a number of character-
tics of the process is a necessary condition in
ilding the model. This operation of formalizing
e economic process is one of the most important
erations in building the model. A mistake at this
age is the most frequent source of incorrect re-
lts obtained from the model of the economic proc-
s.

When the model is prepared, one or another
athematical process is applied to it with the ob-
t of expressing the unknown variables in the
odel through the known. At the beginning the equa-
n or system of equations making up the model are
pressed in a form convenient for their solution.
en the roots of the equation are found, that is,
e solution of the model. This stage belongs in the
ld of mathematics.

The simplest economic processes can be ex-
essed with the aid of a single function — linear,
ponential, inversely proportional, etc. Each of
ese functions describes a definite type of quanti-
ive dependence of the function on the argument.
addition to functions of one variable, functions
many variables are employed.

When it is difficult to establish at once the rela-
nships between the variables themselves, re-
urse is had to establishing the relationships be-
een them and their increments. Then differential
ations are derived through which the interde-
ndence of the functions themselves may be de-
ed.

Complex economic processes are modelled with
aid of a whole system of equations. Systems of
ear algebraic equations are used to describe
tic processes (the distribution of the already pro-
ced product, etc.). For a description of dynamic
ocesses with changes over certain intervals of
e, recourse is had to a system of equations in
al differences which, within the limits of the re-
tion of the interval of time, lead to systems of
ferential equations (ordinary or, in the
re complex case, in partial derivatives), as well as to integral and functional equations.

After solving mathematically the given equation or the system of equations the results obtained must be interpreted and analyzed from an economic point of view. In doing so, the correctness of the results obtained should be checked.

In theoretical economic analysis mathematical models serve to reveal the quantitative relations between economic categories, the magnitudes of one or another phenomenon.

A classic example of this is the mathematical model of the rate of profit analyzed by Karl Marx in the third chapter of Volume III of Capital, establishing the relationship between the rate of profit (p'), the rate of surplus value (m'), the organic composition of capital ($\frac{c}{v}$) and the speed of turnover of capital (n): $p' = \frac{m.n}{c+v}$ which is reduced after dividing the numerator and denominator by v to the formula $p' = \frac{m'.n}{\frac{c}{v}+1}$. This model is expressed by a single equation with several variables (m', n and $\frac{c}{v}$).

Karl Marx's models of reproduction serve as an example of mathematical modelling of economic processes with the aid of systems of equations. In analyzing value and material relationships for one year, we have ordinary algebraic equations; in analyzing the changes in these relations over time intervals (for one year) we are concerned with equations of final differences; and in examining changes in these relations for an infinitesmally short interval of time (dt), differential equations.

At the same time mathematical models may be extensively applied in economic research for processing factual data and for revealing quantitative regularities in the formation or dynamics of a definite economic process. Here, the mathematical model makes it possible to better understand the qualitative nature of the given phenomenon.

For instance, in the study of the factors governing the consumer demand of the population the establishment of the quantitative relationship between the magnitude and structure of consumption on the one hand, and the income level on the other, assumes great importance. For this purpose it is necessary to find the mathematical curves that characterize the relationship between the magnitude of consumption of different types of goods and the per capita income level. Making use of this relationship, it is possible to determine the average magnitude of consumption of goods from the income level, which is of substantial help in planning trade turnover and determining the rate of consumption for the planned period.

In such research mathematical methods not only make it possible to establish the strict quantitative dependence between the indices studied, but also to find the extent to which various factors influence the changes in the given index (for instance, the influence exerted by family size, its composition, and the per capita income level on consumption).

The Communist Party directs the efforts of Soviet economists towards the investigation of the laws of the transition from socialism to communism on the basis of generalizing rich historical experience ond factual data. In such research the application of mathematical methods will be of great help. It willl help not only to deepen this research but also to develop it into a form that will be convenient for use in economic practice.

Besides the above-mentioned fields of application, mathematical models can be applied in planning, and first of all for studying the interrelations among industries, districts, and different elements of the economy. The economic indices form an integral system so that the knowledge of a certain part of these indices (the known) makes it possible to determine the other indices (the unknown). Thus, a knowledge of the volume of production and labor productivity is sufficient to determine the planned labor force. With the aid of mathematical models it will be possible to find, by means of the known economic indices, the unknowns connected with them. Electronic computer technique greatly broadens our possibilities in this respect. Whereas 5 to 10 equations with as many unknowns can be solved by hand, electronic machines handle many hundreds of equations with hundreds of unknowns.

The main field in which mathematical models can be applied in planning is in finding the optimum plan solutions for loading productive capacities, the output of goods, the reduction of transport costs, capital investments, etc. Modern mathematics provides economists with a powerful tool for deriving extreme (both minimal and maximal) magnitudes in a system of equations, while the application of electronic computer technique makes possible the practical solution of such problems in the shortest period of time.

Finally, mathematical methods can be used in planning for carrying out various long-range calculations on the basis of mass data (for instance, the calculation of the planned distribution of workers and employees according to wages in raising the minimum wage to 500-600 rubles a month). Such calculations usually require the combination of sample and comprehensive data to obtain a correct result. Mathematical methods not only facilitate such a combination and speed up the solution, but also make it possible to assess the reliability of the sample data employed and the derived final indices.

Mathematical methods in economic calculations may be applied both in planning at plants and in economic councils, and in drawing up the plans f the union republics and the national economy of t USSR as a whole.

At the present time the mathematical models adapted to internal factory accounting and partic lar accounting operations within the economic co cil or the economic area have been formulated be of all. This concerns first of all the methods of linear programming of economic factors and resources. This has to do primarily with the techn cal and economic aspects of validating the plans, matter which lends itself to mathematical modell ling comparatively easily (calculations of the loa of equipment, the work schedule, shipments, etc. A certain amount of experience, partially describ in our literature, (1) has been accumulated in thi field.

The preparation of mathematical models in dr ing up a plan for the national economy is a more difficult problem. These models must take into account not only technical and economic but also social-economic relations. At the present time only the first steps are being made in certain sp cial fields (first of all, in wage and income calcul tions). The preparation of comprehensive mode of reproduction is a matter for the future.

It is evident that the fields in economics and planning in which mathematical models can be a plied are multifarious. Let us consider several typical economic models that can be used in plan ning.

2. Linear Economic Models

Here is a balance table of inter-industry relations in the national economy (see table on the t of the following page).

The inter-industry material and value relatio in the national economy can be expressed by a s tem of linear equations.

1. Equations of the distribution of produced goods for productive consumption and for finish output (relations according to the rows of the ba ance sheet):

$$\begin{array}{l} X_1 - X_{11} - X_{12} - \dots - X_{1n} = Y_1 \\ X_2 - X_{21} - X_{22} - \dots - X_{2n} = Y_2 \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ X_n - X_{n1} - X_{n2} - \dots - X_{nn} = Y_n \end{array}$$

In the general form this system of equations i written thus:

$$x_i - \sum_{k=1}^{n} x_{ik} = Y_i \qquad i = 1,2 \dots$$

	Distribution of Output for Productive Consumption in Various Branches of Industry				Final Product Y			Total Output X
					Total Y	Including		
	1	2	....	n		Non-Productive Consumption	Accumulation of Productive Capital	
Branches of Industry								
1	X_{11}	X_{12}	....	X_{1n}	Y_1			X_1
2	X_{21}	X_{22}	....	X_{2n}	Y_2			X_2
.	.	.	....	.	.			.
.	.	.	....	.	.			.
.	.	.	....	.	.			.
n	X_{n1}	X_{n2}	....	X_{nn}	Y_n			X_n
ayroll Fund v	v_1	v_2	....	v_n				
et income m	m_1	m_2	....	m_m				
ocial Production Costs P	P_1	P_2	....	P_n				

If we introduce the coefficient a_{ik}, characterizing
ie direct expenditures of the output of industry i
ır the production of a unit of output of industry k,
ıen $x_{ik} = a_{ik}\, x_k$ and the system of linear equa-
ons will assume the form:

$$x_i - \sum_{k=1}^{n} a_{ik} \cdot x_k = Y_i \qquad i = 1,2 \ldots n$$

This system of equations can be expressed both
natural and in value indices.

2. Equations of social production costs (rela-
ons according to the columns of the balance
ıeet):

$$\begin{aligned} x_{11} + x_{21} + \ldots + x_{n1} + v_1 + m &= P_1 \\ x_{12} + x_{22} + \ldots + x_{n2} + v_2 + m_2 &= P_2 \\ \ldots\ldots\ldots\ldots\ldots\ldots & \ldots\ldots \\ x_{1n} + x_{2n} + \ldots + x_{nn} + v_n + m_n &= P_n \end{aligned}$$

In the general form this is a system of linear
ıuations of the type:

$$\sum_{i=1}^{n} x_{ik} + v_k + m_k = P \qquad k = 1,2 \ldots n$$

$\sum_{=1} x_{ik}$ characterizes the material expenditures
the production of output k. After the introduc-
on of the coefficients of expenditures a_{ik} the fol-
wing system of equations is derived:

$$\sum_{i=1}^{n} a_{ik} x_k + v_k + m_k = P_k \qquad k = 1,2 \ldots n$$

This system of equations can be expressed only in value form.

3. Equations of the relations between output and production costs, the material and value components of output:

$$\text{a)} \quad \sum_{k=1}^{n} a_{ik} x_k + Y_i = \sum_{i=1}^{n \text{ (in the given branch of industry)}} a_{ik} x_k + v_k + m_k$$

$$\text{b)} \quad \sum_{i=1}^{n} \sum_{k=1}^{n} a_{ik} x_k = \sum_{k=1}^{n} \sum_{i=1}^{n} a_{ik} x_k,$$

that is, the material composition of the compensation fund is equal to the total value of the means of production expended in production;

$$\text{o)} \quad \sum_{i=1}^{n} Y_1 = \sum_{k=1}^{n} (v + m)_k,$$

composition of the national income is linked with its value magnitude.

Using the systems of linear equations given above, the unknown magnitudes in the balance sheet of the inter-industry relations can be determined by means of the known magnitudes.

For instance, in the equations of distribution with the known coefficients a_{ik} and the final demand Y_i, the magnitudes of the entire product in different branches can be found (determine x_i). Given the coefficients a_{ik} and the volume of output and the final demand in a number of branches, it is possible to derive the volume of output and the final demand in other branches. What is important is that the number of unknowns should not be more than the number of equations (i.e., not more than n).

The solution of the above system of linear equations for finding x_i will be:

$$x_i = \sum_{k=1}^{n} A_{ik}Y_k \qquad i = 1,2 \ldots n,$$

where A_{ik} represents the coefficients of the relations between the entire and the final product and characterizes the full expenditures of the output of other branches for the production of a unit of output x_i (as distinct from the coefficients a_{ik}, characterizing only direct expenditures).

Having once calculated the full coefficients of the expenditures A_{ik}, it will always be possible to easily find the magnitude of x_i for the given magnitudes of Y_i. (2)

It is not difficult to see the importance of the linear model of inter-industry relations in drawing up a consolidated material balance sheet, in coordinating the planned indices for the different branches of industry and in establishing conformity between the material and value structures of the national income and of the production volumes of diverse products.

Analogous models can be drawn up for separate economic areas. At the present time the laboratory for the application of mathematical methods in economic calculations of the Siberian Branch of the USSR Academy of Sciences is preparing models of the production and distribution of goods within the limits of an economic area (with due regard for its mutual relations with other areas of the country). On the basis of such models a linear model of inter-district relations will be prepared in the future. The importance of this cannot be overestimated.

The linear model of inter-industry relations can be used at the same time for a number of other purposes.

First, it can be used to provide a basis for price setting. In the course of the simultaneous reduction in the wholesale prices of many items, the influence which the lower prices of these items exert on each other can be exactly calculated with the aid of this model. It can also be used for computing expenditures on the production of diverse goods, expenditures which determine their value. This would be of great importance in improving the price-setting system.

Second, it can be used to calculate the full labor expenditures on the production of individual items The calculations are made in accordance with the following system of equations:

$$c_i = \sum_{k=1}^{n} a_{ki}c_k + b_i \qquad i = 1,2 \ldots n,$$

where c_i stands for the full labor expenditures pe unit of production, b_i for direct expenditures (living labor), $\sum_{k=1}^{n} a_{ki}c_k$ for indirect labor expenditures (past labor), which take place in connection with the expenditures of raw materials, supplies, and other means (on which, in turn, labor is expended) on the production of a unit of output i. Th calculation of the full labor expenditures on the production of individual items will be of great hel in determining the labor consumed in one or another type of production, in the planning of the labor force, as well as in the more exact calculatio of labor productivity (the calculation of productivity by the labor method). (3)

Third, this linear model can be used for calculating the full capital investments in one or another project (analogously to the calculation of th full labor expenditures). Thus, the construction c a thermal power station requires not only direct capital investments but also additional investmen in coal mines (to supply the station with coal), etc At the same time the construction of hydroelectri power plants does not require additional investments in coal. It is self-evident that in the determination of the effectiveness of capital investments it is precisely the full investments that hav to be taken into account. Calculations of the full capital investments together with the proper consideration of the time factor in drawing up projec will provide firmer economic grounds for investments in fixed capital.

For use in planning practice, linear models of inter-industry relations covering hundreds of branches must be prepared. Their solution, whic requires billions of operations, is possible only with the aid of electronic computers.

The main difficulty in applying mathematical methods in the field of inter-industry relations co sists in the accumulation and processing of the in tial statistical and planning indices (first of all, t coefficients a_{ik}). Extensive work in this area is being conducted at the present time by the Central St tistical Administration of the USSR. This labor-con suming work will be justified, for the coefficients of expenditures are necessary not only for drawing up chessboard balance but also for the indicated calcul tions on price setting, labor, and capital investment

3. The Linear Programming of Economic Factor

Linear programming is a mathematical method

finding the optimum variant. In economic prac-
ce this method can be extensively applied in
lving approximately the following types of prob-
ms:
1. A production problem — for instance, the dis-
ibution of the production of definite items accord-
g to the type of equipment with the object of
taining the maximum output of the given assort-
ent. The broad category of production problems
so includes such problems as drawing up an
timum work schedule, determining the amount of
eliminary work done, the most rational utiliza-
n of skilled labor, the distribution of the produc-
n program among a number of plants, shops,
c.
2. A transport problem — for instance, assigning
al suppliers to consumers in such a way that,
ven the equality of resources consumed, the cost
coal shipments should be at a minimum. This
cludes also the problems of the most favorable
riant of mixed shipments via various kinds of
nsport, the determination of the routes and the
quired means of transport, etc.
3. The problem of determining the most effec-
e variant of capital investments. This also in-
des the choice of the construction site, deter-
ning the routes of planned roads, etc.
4. The problem of optimum assortments. For
stance, this includes the problem of selecting,
m the numerous physiologically equal assort-
nts of food products based on scientific norms
rked out by medical men, the most rational as-
rtment applicable to the given area with due re-
rd for the possibilities of local production,
pments from other localities, national traditions
consumption and a number of other conditions.
h work is now being conducted in connection with
elaboration of the long-range plan.
As distinct from the model of inter-industry re-
ions, which can be applied only on the scale of
economic area or of the national economy as a
ole, the methods of linear programming can also
applied at plants and even in shops. These
thods are also employed in solving technical
blems (the economical cutting of a metal sheet,
aining the necessary mixtures of petroleum prod-
s and chemical matter, etc.).
The practice of applying linear programming in
country and abroad testifies to the great ef-
tiveness of this method. For instance, in Mos-
the use of linear programming in determining
optimum plan for the transportation of sand
m several piers to construction sites yielded an
nomy of 11.3% against the manually planned
ight turnover. In money terms this economy
ounted to nearly 2.5 million rubles a year, while the cost of the calculation was only 500-600 rubles.

Evidently the greatest economy in the near future on a national scale could be achieved by the introduction of linear programming in the practice of material-technical supply. As distinct from a number of other areas, in this case the situation is more favorable with regard to the initial data required for computations (consumers' orders, the suppliers' production plans, the radius of shipments, the number of cars available, etc.). Special methods have been elaborated for solving such problems not only for a single product but also for interchangeable products, taking into account all the possible complications of the problem (the capacity of the railways, the necessity for the return of empty cars, etc.). The application of these methods will not only make it possible to obtain great economies by eliminating irrational shipments but will also sharply reduce the time required for drawing up and improving the quality of the plans for material-technical supply.

At the present time calculations for drawing up plans for the material-technical supply of coal to the country are being carried out in the Institute of Electronic Control Machines of the USSR Academy of Sciences jointly with the Academy's Council on Productive Forces and the Economic Research Institute of the State Planning Committee. Experimental calculations for the rational shipment of coal in Eastern Siberia and the Far East have been already made. They show the great advantages of introducing mathematical methods and electronic computer technique in this field. The same organizations have begun to work out a mathematical model for the total fuel and power balance of the country, taking into account the interchangeability of various kinds of fuel.

Despite the great importance of linear programming methods for economic practice, they should not be overestimated. Such an overestimation takes two forms. First, other methods of finding the optimum variant in economic calculations — the methods of solving problems of extremes with the aid of differential calculus and variation analysis, the employment of the methods of probability theory, etc. — may be ignored. It is sometimes forgotten that linear programming is applicable only to linear relationships and cannot help in solving problems involving non-linear relationships. Second, linear programming is considered the main tool in national economic planning, making it possible to draw up an optimum plan for the entire economy, including long-range plans. The narrow technical economic approach that is suitable for solving problems in the plant or shop can in no way be suitable for the national economy developing according to definite economic laws.

4. Mathematical-Statistical Economic Models

Mathematical statistics has long been use in economic calculations. Improvements in its methods on the one hand, and the expansion of the data given in statistical accounts on the other, open up new possibilities for the construction of mathematical-statistical models in diverse economic fields.

Mathematical statistics provides a number of highly effective methods in the study of one or another economic process on the basis of a comparatively small number of observations, offers the tools for assessing the correctness of these observations, includes the methods of establishing quantitative relations among various phenomena, and has worked out criteria for testing the correctness of one or another hypothesis, etc. These methods can be extensively applied in all the links of economic activities — from a section in a shop to national economic planning.

With the aid of correlation analysis various firmly grounded norms can be established — the norms for working capital and the labor force at various plants. It can also be used to determine the criteria for the classification of plants, etc. These methods make it possible to determine the close relationship, for instance, between the number of office employees and the number of workers, the amount of fixed capital of plants, etc., and to derive the degree of correlation among these indices. This should be taken into consideration in drawing up the corresponding norms.

Mathematical-statistical models are of special importance in the study of living standards and in providing a firm basis for the measures designed to raise the population's material welfare.

The model for the distribution of workers and employees according to pay brackets enables us to establish, first of all, the relation between this distribution and the conditions of labor remuneration (basic rates, wage scales, job classification handbooks, bonuses, etc.), which makes it possible to plan these wage scales, basic rates, bonus provisions, etc., so as to take into account their influence in raising the wages of low and medium-paid personnel and reducing the difference between their wages and those of highly-paid personnel. Is there any need to stress the importance of correct planning in this field in the light of the extensive work being done in the Seven-Year Plan period to adjust wages in all branches and to further raise the pay of workers and employees in the low-paid brackets?

At the same time, with the aid of this model an on the basis of the computation of the factors influencing the distribution of workers according to pay brackets, we can make long-range calculatio of such a distribution for the coming years. In particular, such calculations for every year of th Seven-Year Plan have already been made. These calculations are necessary to estimate the additional state expenditures on raising the minimum wages and pensions in connection with the aboliti of taxes on the population in the current Seven-Year Plan period and for a number of other meas ures in the field of raising the well-being of the population.

In brief, the essence of the mathematical-statistical model as applicable to piece workers one type of job consists in the following. Wage rates for the various wage grades are determine from data on the wage rate for the first grade an the wage scale coefficients. The distribution of these workers by piece wage earnings is calculat with the aid of the function of the distribution of workers according to the extent of norm fulfillm and the data on the number of piece workers by wage grades and their basic wage rates (by deter mining the variation in wages around the basic wage rate for each grade). Then the amounts of bonuses given to the workers are taken into account and thus the distribution of the workers ac cording to total earnings is determined.

The Joint Economic Department of the Commi tee on Labor carries out these calculations in practice jointly with the Institute of Electronic C trol Machines. To check on the correctness of t formulated model, these groups first calculated the distribution of workers in wage brackets on t basis of the new wage provisions in force in the cement industry, where wage adjustments were carried out in 1958. The comparison of the calculated and the actually existing distribution con firmed the correctness of these calculations.

Carrying out such work for all branches and categories of workers, plus taking into account t regional coefficients, supplementary pay for lengthy service, etc., requires a tremendous amount of calculations and can be handled only b electronic computers. Moreover, the applicatio of electronic machines makes it possible to mak the model more complex and bring it closer to t real state of affairs. Such calculations are now being made.

Attempts are being made at the reverse kind calculations: given a definite distribution of wo ers according to pay brackets corresponding to concrete minimum wage, the problem is to find pay provisions corresponding to this distributio

ith certain limiting factors, of course: the wage
ades of the scale, higher compensation for heavy
d hot jobs, etc.).

The building of mathematical-statistical models
the formation of the population's income will be
great importance. In the field of material wel-
re the task is to achieve a more rapid growth of
come for the relatively low paid families and, on
is basis, to reduce the differences between the
ving standards of various strata of woriers. This
being attained both by increasing the wages of
orkers in the low-wage brackets and reducing
age differentials, as well as by developing social
nsumption funds, first of all children's institu-
ons and boarding schools, which are most advan-
geous for families with many children and rela-
vely low incomes. In addition, changes in family
mposition due to demographic and social condi-
ons markedly affect the formation of the family's
come.

A consideration of the factors determining the
rmation of the incomes of various family groups
d their quantitative expression in the correspond-
g model will make it possible to better analyze
e reasons for reducing differences in living
andards among certain family groups, to deter-
ne the effect of one or another measure for rais-
g the people's well-being on the amount of in-
me of certain family groups (for instance, the
ect of raising minimum wages on the incomes of
relatively low-income families), to make long-
nge estimates of the rise in the real income of
low-, medium- and high-paid family groups,
.

The preparation of such a model is a very com-
x mathematical and statistical task not only be-
use of the many-sided interdependence among the
y factors forming family incomes (each of
ich, in addition, has a distributive character —
distribution of family heads according to pay
ckets, the distribution of families according to
number of breadwinners and dependents, etc.),
chiefly because of the need to combine in a
ecial way sample and comprehensive data to ob-
n reliable results. Despite the difficulties en-
ntered in this work, it can be considered close
completion. (4)

n analogous problem faces us in computing the
tors making up the population's expenditures —
consumption of material goods and services.
ssibly this is even a more difficult problem,
ce here we will have to begin with the data on
expenditure side of budget studies, making use
he standard estimates for the free or preferen-
consumption of services (education, health
e, etc.), data on trade turnover, the results of the balance of money incomes and expenditures of the population, etc.

The result of all this work on determining the factors making up the incomes and expenditures of the population will be the calculation of a differentiated balance of the incomes and expenditures of working people's families, i.e., a balance of the incomes and expenditures for families with different income levels. The mathematical-statistical model of such a balance will include the models carrying the formation of income and the composition of the expenditures of the population. This balance, which is beginning to be drawn up for the first time in our country and which has no precedent in world statistical practice, will subsequently prove to be a very important document in planning a rise in the people's well-being.

5. Differential and Functional Economic Models

The individual economic models dealt with above express the dependence of some particular economic process in expanded socialist reproduction. As modelling comes to embrace one field of planning after another, the problem of synthesizing these models into consolidated mathematical models of expanded socialist reproduction will arise. Attempts should already be made to build simple models at first and then ever more complex (which means closer to reality) models of expanded socialist reproduction.

By their nature these will be dynamic models. But dynamic processes require other mathematical relationships for their expression. Linear algebraic equations will hardly be able to express dynamic laws with adequate precision and they will be replaced, as equations of static models, by various differential and integral equation systems which correspond more to the nature of dynamic processes.

The development of the national economy is determined to a large extent by the amount and structure of accumulation. In this connection, several years usually pass between capital investments and the output of goods from the erected enterprises. Therefore, in the system of differential equations of reproduction this factor of the time lag between the output of goods and the capital investments must be taken into account.

The basis of the dynamic models of expanded reproduction will be the latter's central relationships — between the subdivisions of social production, between the elements of the social product, accumulation and consumption, fixed and working capital on the one hand and output on the other, etc. These relationships will be made many times more complex by industrial, branch, district, distributive and other aspects. Taking this into consideration, experiments with the simplest consolidated models of socialist reproduction in which the most important economic laws would be reflected should begin right now. (5) Special attention should be paid here to the economy's major structural and dynamic indices, changes in which lead to changes in rates of growth and proportions (in particular, the norm of the product for society, the rate of accumulation, the standard capital-output ratio, the relation between fixed and working capital, the combination of economies of living and materialized labor, interrelations between economies of total labor and simple labor, etc.). What is required in this field is fundamental research based on factual material.

The perfection of the theory and methodology of the national economic balance, the elaboration of models and indices of the dynamic balance to be calculated in material and value terms so as to disclose the most important structural and dynamic indices, all this will be of considerable help in this important work.

With such a dynamic national economic balance (both a reported and a planned balance), it would be possible to formulate on its basis, at least in general form, a consolidated mathematical model of expanded socialist reproduction.

Big tasks also face Soviet mathematicians in elaborating the methods of finding the optimum variants for a system of differential and functional equations. This applied branch of mathematics is only beginning to develop under the name of dynamic programming. The progress of the major natural sciences has always enriched mathematics and produced its new methods. There is hardly any doubt that the extensive application of mathematics in economic calculations will enrich not only the work of planning but mathematics itself. In its turn, the application of mathematical methods will help to develop economic science and improve planning.

It is necessary to stress once more that a deep knowledge of the essence of economic processes, their casual relationships and laws is the main condition for the scientific building of mathematical models. The correct application of mathematical methods in the social-economic field can be achieved only on the basis of Marxist-Leninist political economy.

In this connection we cannot pass by the application of mathematics in bourgeois political economy. The nearly 80 years of experience in the application of mathematical methods in vulgar political economy (from the times of Pareto, Jevons and other supporters of the mathematical school in theoretical economics) shows quite clearly its sterility — no scientific economic results have been attained. As before, the studies are concerned with competition, the interrelations of demand and supply, of the seller and buyer, without even the slightest hint of revealing the reasons fo these superficial phenomena in economic life. Research has shifted from "microeconomics" to "macroeconomics," the range of problems has be expanded, but not at all the depth of the studies. The class vision of the bourgeois economists permits them to notice only the foam on the surface economic life and hides from view the deeper currents.

The applications of mathematical methods by bourgeois econometricians in the social-economi field are essentially unacceptable for economics and economic activities.

The application of mathematical methods in technical-economic calculations in capitalist cou tries has been widespread in the postwar period and should be approached with a different yardstick. There is much that is superficial and crud in this field too. But there is some useful material here. This especially concerns several works on the application of the methods of linear and dynamic programming, the theory of expectations, modern methods of selection, etc. The study of these methods may be of practical value.

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The preparation of mathematical models of ec nomic processes is the main link in the application of mathematics and electronic technique in planned accounts. In addition to raising the quali of planning and its precision, it holds out the promise of direct economies of billions of rubles due to the better loading of production capacities the selection of more effective variants of capita investments, the reduction of transport costs, e

The Soviet state is devoting great attention to these questions. A department to train students specializing in planning with the application of el tronic computer technique has been set up at the Moscow State Economics Institute. A computer center is being set up under the State Planning Committee of the USSR. Extensive work on calculating a chessboard balance of inter-industry lations with the aid of electronic computers, on solving transport problems by the methods of li ear programming, etc., is in progress at the Ce tral Statistical Administration of the USSR and a a number of scientific research organizations.

Planning workers in cooperation with Soviet s entists — economists, mathematicians, technica experts — should undertake the broad introducti modern mathematical methods in planning on the isis of the Marxist-Leninist teachings, the great- st possible application of powerful electronic com- iter technique in economic analysis and planning.

Footnotes

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(1) For instance, a scientific team of the Cehliabinsk olytechnical Institute, jointly with workers of the lo- l tractor plant, applied the methods of linear pro- amming for drawing up an optimum timetable for ork and organization of the rhythmic course of pro- iction at this plant, which yielded a positive effect (see e magazine Vestnik Mashinostroenia, 1958, No. 10).

(2) A more detailed account of a model of inter-industry relations applicable to planning is given by G. Grebtsov in Planovoe Khoziaistvo, 1959, No. 6.

(3) See "Statistical Methodology in the Study of Labor Productivity in the National Economy of the USSR," State Statistical Publishing House, 1958 (report by E. G. Liberman).

(4) In this connection see the first section of the book Metodologicheskie voprosy izucheniia urovnia zhizni trudiashchikhsia, Moscow, State Publishing House of Social and Economic Literature, 1959.

Voprosy Ekonomiki, No. 6, 1960

NEMCHINOV:

he Use of Mathematical Methods in Economic esearch and Planning

In today's conditions of building communism so- ilist society requires far higher scientific stand- ds. The founders of Marxism-Leninism pointed that the function of science is not merely to rn the laws of nature and society, but also to rk out the ways and means of placing those laws the service of social progress and the full de- opment of the material and cultural standards of members of society. This makes it necessary the science of economics to solve in good time problems posed by socialist construction, for practical efforts today require improvement in application of the known laws of development of ure and society.

uided by the experience in socialist construc- n, the Communist Party and the Soviet govern- nt are perfecting the planning and management he national economy, ensuring the successful ward movement of our society in communist struction. In connection with this progress, the ndards of requirements of economic science de been further raised. Yet economies continues ag behind the needs of actual practice.

he Soviet public today regards the economist as a social engineer whose duty it is to ensure the working out of a system of economic measures for the continuous and accelerated development of social production for the purpose of producing an abundance of material and cultural values. Today, the results of economic research must be raised to such a degree of exactness and concreteness that they will convert the laws which have been apprehended into an efficient, scientific and exact mechanism for the planned direction of the national economy.

Deliberate use of economic laws requires knowledge not only of the qualitative but also of the quantitative aspect of economic phenomena. Without a theoretical approach to analyzing the quantitative relationships in the socialist economy, it is impossible thoroughly and deliberately to use the economic laws of socialism, in particular to improve scientific planning for the purpose of developing the national economy and culture. Yet, along with certain problems of theoretical qualitative analysis of the ways and means of building communism, a quantitative analysis of economic phenomena has today become one of the "weak points" of Soviet economics. This is due not only to the much higher requirements set for Soviet economic science, but also to a certain underestimation by individual economists of the need for a scientific analysis of the quantitative side of the economic processes at work in the socialist national economy.

While properly concentrating their attention on studying the qualitative features and advantages of the new, socialist mode of production as compared with the capitalist, some economists have begun to regard the science of economics incorrectly, and in particular political economy, regarding it merely as a science of qualitative economic laws and losing sight of the vast importance of a theoretical approach to analyzing the quantitative aspect of the economic laws of development of socialist society.

Until quite recently some of our economists even denied that a theoretical approach to the quantitative side of the laws of development of socialist economy was possible and were ready to hand over to statisticians the study of the quantitative side of economic progress, regarding it as a field for concrete empirical research only. Yet a scientific analysis of economic processes and phenomena connected with the laws of planned (balanced) development of the national economy, of socialist distribution according to work performed, of the economy of social labor, processes connected with the law of value, and so on, is inconceivable without a theoretical approach to the quantitative side of economic laws. For this reason the political economy of socialism cannot be limited only to a qualitative analysis. Basing its theoretical quantitative analysis on a thorough scientific knowledge of the qualitative features of a socialist economy, the science of economics can and must become an exact science under socialism.

The basis of every scientific method is the dialectic unity of the qualitative and quantitative analysis of the phenomena of nature and society. A qualitative analysis must not only precede an all-sided quantitative analysis but also be accompanied by it. Of great importance for planning the socialist economy is theoretical research in the sphere of quantitative relationships. Today the need for raising the standard of quantitative analysis of all aspects of the development of the planned economy has become urgent; it must be placed at the service of socialist construction and the further improvement of planning.

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In every science a quantitative analysis is inseparably bound up with the use of measures and numbers, with mathematical methods, and in economic science it is bound up, in addition, with extensive use of statistical methods, including the methods of mathematical statistics.

In economics, as is the case in all other sciences, the chief condition for the application of mathematical methods is a preliminary qualitative analysis of the nature of the economic phenomena being studied. Otherwise there arises the danger of substance disappearing and leaving nothing but equations, and secondary indexes beginning illegitimately to take the place of meaningful social and economic categories. On the other hand, the history of the development of any science shows that it becomes exact after its main criteria and basi laws are given a quantitative, mathematically formulated expression. Economic science is no exception.

The science of mathematics requires precise formulation of the initial conditions and characteristics of the phenomena studied as an essential prerequisite for consequent logical constructions. Mathematicians always have in view the limitation on the correctness and truth of conclusions based on these initial preconditions. Infraction of this principle stems from an abuse of mathematics, an abuse of which the science of mathematics is certainly not guilty itself. Such abuse, however, often takes place, particularly in the social and economic sciences. And those who apply mathematical methods in studying complex socio-economic processes that are subject to the laws of historical change of their qualitative features should be cautioned against such errors. It should always be remembered that mathematics has been compared to a millstone and if you place weeds under it you will never get wheat flour.

While warning against the abuse of mathematics we must at the same time not underestimate the highly positive and salutary role played by mathematics in improving other sciences. Marx believed that a science attains perfection only when it has succeeded in making use of mathematics. (1) Testifying to this estimate by Marx are the memoirs of M. Kovalevskii (2) and mathematical notebooks left by Marx.

Proper scientific application of mathematical methods in the various sciences undoubtedly enriches them and helps improve them, but abuse of mathematics could, of course, play the part of a "Trojan horse," making for the penetration of an alien and inimical ideology. To avoid this, the necessary measures should be taken, one of which is to raise the standard of mathematical knowledg and mathematical culture of our economists.

Some economists believe that another precauti is to fix the limits of application of mathematics in economics. Yet we should speak not of the lim of application of mathematics in economics, but only of the primacy of a preliminary qualitative

nalysis as the basic condition for scientific appli-
ation of mathematical methods and of the need for
aking into account the complexity of the conditions
f the use of mathematics in the socio-economic
eld. Nor should it be forgotten that there are
conomists who still hold the incorrect view that
ne application of mathematical methods in eco-
omics is useless and even harmful.

In employing mathematical methods in economic
esearch we should not, on the one hand, forget that
athematics plays a subsidiary role in the sci-
nces in which it is applied, but on the other hand,
e should not reduce the importance of mathemat-
s to a narrow, technical feature and underesti-
ate its great possibilities for developing the theory
f the particular field of science in which it is used.

Translation of the respective scientific ideas into
ne strict and exact language of mathematics leads
o more precise definition of scientific concepts
nd to perfection of the particular scientific disci-
lines. The construction of clear economic-
athematical models permitting the conversion of
ne established parameters of those models into the
nguage of computing technique enables us to deep-
n and make more precise our ideas of the quanti-
tive aspects of the laws inherent in a socialist
conomy at the individual stages of its development,
nd thus to a certain extent also of their qualitative
spects. The development of such economic-
athematical models permits improvement in the
ethods of economic and planning calculations
eeded for the compilation, correction and fulfill-
ent of our national economic plans.

It should be stressed that up-to-date electronic
mputing machines can be used in economic re-
arch and in planning only on the basis of the ex-
nsive application of mathematical methods, for
ese machines only process data formulated in the
nguage of mathematics.

Economic-mathematical models make it possible
check our initial assumptions on the dynamics of
e quantitative relationships between the indi-
dual aspects and elements of the economy, as, for
ample, between accumulation and consumption,
tional income and capital investments, depart-
ents I and II of social production, and so on, by a
mparison of the quantitative characteristics fol-
wing from these assumptions with the actual data
served.

The increasing attention given to analysis of the
antitative side of economic phenomena and to the
velopment of the mathematical methods of this
alysis stems from the progress of the Soviet
onomy, the increasingly complex tasks which we
e set ourselves in the transition to the building
a communist society.

The greater attention given to theoretical and practical questions of analysis of the quantitative interconnections of the Soviet economy, far from contradicting the basic principles of the Marxist-Leninist political economy of socialism, actually follows directly from them. Yet some Western economists see in this signs of a certain deviation from Marxist-Leninist ideology. To illustrate, the January 1960 issue of the magazine Foreign Affairs carried an article by W. Leontief, an American economist, in which he asserted that Soviet economists are merely using the "achievements" of bourgeois political economy in their application of mathematical methods in economic research and planning. The article contains many contradictions and improbable assertions. For instance, while admitting that optimum programming methods first originated in the Soviet Union, Leontief at the same time denies the fact that the methods used in analyzing production links among branches of industry were also first worked out in the USSR in drawing up the national economic balance-sheet for 1923-1924. In denying the priority of Soviet economists and statisticians in working out the method of inter-industry production links, Leontief, in particular, puts forward the obviously improbable version that his article printed in issue No. 12 of the magazine Planovoe Khoziaistvo for 1925 (Leontief at the time was completing his studies in the Economics Department of Leningrad University) was a translation from an article carried by a German magazine. (The article was written by him on the occasion of the publication of the balance-sheet of the national economy of the USSR for 1923-1924, which had just then appeared in the newspaper Ekonomicheskaia Zhizn.) He said nothing about the fact that the mathematical equations used by him in his work The Structure of the American Economy are essentially the equations worked out by the Leningrad economist and mathematician V. Dmitriev (the author of Ekonomicheskie Ocherki, 1904) and they differ from Walras' equations.

Leontief's assertion that the Soviet method of balances merely raises important economic problems but does not solve them does not correspond to the facts either. The method of balances gives an answer to the most important economic questions, establishing a connection between the structural characteristics of the national economy and its dynamic factors. This method makes it possible, among other things, to determine the degree of dependence of the coefficient of expanded reproduction on the difference between the net production of department I (production of the means of production) and the material costs of department II (production of articles of consumption). The use of these balanced economic interrelationships furnishes a thorough explanation of the high rates of economic development of the Soviet economy, which can hardly be said about Leontief's primitive formula (which he identifies with Adam Smith's economic thesis and Benjamin Franklin's "homely" formula), according to which an expansion of income requires that a constantly increasing share of it be channeled into productive capital investment at the expense of consumption. If the balanced interrelationships of the structural economic characteristics and dynamic factors are properly understood, productive capital investments not only do not require a restriction of consumption, but on the contrary they ensure a steady rise on consumption over a long period, a rise which would be impossible without the corresponding earlier productive capital investments.

Properly and scientifically used, the Soviet method of balances permits us to reveal with sufficient thoroughness and detail the entire complex structure of the economic mechanism, and on the basis of knowledge of the laws of the functioning of the economy helps to scientifically regulate the course of economic development, ensuring a high rate of economic growth.

Probably what hinders bourgeois economists from understanding the full importance of the method of balances used in Soviet planning calculations is their fear of a deeper knowledge of the mechanics of operation of economic laws, laws which open up the prospect — an "undesirable" one for bourgeois economists — for attempts to regulate the national economy, which, incidentally, Leontief admits in his article.

Thorough scientific research in quantitative interrelations is expressed in the USSR in the application not only of the method of balances but also of other methods used by our planning agencies.

How incorrect is Leontief's notion of the methodology of Soviet planning can be seen from his assertion that Soviet planning methods do not actually differ from the methods employed during World War II by the American War Production Board, the British Ministry of Supply and their counterparts in Germany. He fails to see the profound fundamental difference between Soviet planning and the methods of intervention used by military circles in the national economy. However, progressive Western economists and sociologists rightly hold that only the aggregate of social measures which systematically assure a country's economic growth and which are taken for the purpose of raising the material and cultural standards of the population may be called planning. At the Fourth International Sociological Congress held in Italy in 1959 this viewpoint was graphically expressed in the report of Myrdal and Bettelheim. However, in economic literature abroad national economic planning is us ally erroneously identified with any system of long range synthetic economic computations and with programming technique. Such, for instance, are some of the documents covering Asian countries put out by the Economic and Social Council of the United Nations.

Carried away by his "manipulator aspect," Leontief goes even further. He not only complete denies the fundamental special characteristics of Soviet planning but even asserts that there are no principles whatever underlying the methodology and technique of planning in the USSR, since neith he nor other bourgeois economists have been able to discover any. This assertion is accompanied b another alleged paradox involving an imaginary c trast between the unparalleled successes in trans forming the earlier technically backward Russia into a great industrial power and an imaginary de cline in Soviet economic science. However, the rapid economic advance of a country is incompati ble with a decline of economics. Our country's rapid economic expansion certainly is based on th achievements of Marxist-Leninist economic thoug achievements which were expressed in the correc and scientific principles underlying Soviet econom ic policy. And Leontief's statement that the communist leaders are their own economists merely testifies to the fact that in our country economic practice and theory are closely interwoven. The scientific correctness and accuracy of the fundamental principles of Marxist-Leninist economic theory are undoubtedly the major condition for ou practical achievements in the economic construction of socialism.

The greater attention given to the theoretical approach and the more profound analysis of quantitative interrelations in the country's economy should make our economic and planning calculations even more accurate. Improvement and gre er accuracy of economic and planning calculatio far from altering the principles of Soviet econom policy and of national economic planning, actually follow from them. They stem only from the furth complexity and expansion of the Soviet economy.

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Of late, numerous investigations in the field of econometrics and mathematical economics have been undertaken in foreign literature. Since the war many books have been published and special magazines put out and special international conferences have been convened to examine the appl cation of mathematical methods in economic research.

In literature abroad econometrics is generally
nderstood to be research which combines the meth-
ds of economic theory, statistics and mathematics,
hile mathematical economics is viewed as similar
esearch but without statistical concretization of
conomic parameters.

In Soviet economic literature econometrics and
athematical economics are treated differently.
conometrics is generally understood to be a par-
cular school of bourgeois political economy based
n the theory of marginal utility, and mathematical
conomics is identified with the Anglo-American
ubjective mathematical school in political econ-
my. This treatment is completely logical, for in
conometric research and in theoretical works on
conometrics and mathematical economics abroad
e representatives of the marginal utility and the
ourgeois subjective mathematical school pre-
ominate.

What should be our attitude to econometrics and
athematical economics? We believe that it should
e determined by Lenin's well-known thesis: "It is
e thing not to shut your eyes to bourgeois sci-
ce, to follow it and make use of it, but to regard
critically and not give up the integrity and unity
one's ideology, but it is another thing to yield to
urgeois science and repeat, for instance, those
rds about the 'tendentiousness' of Marx, and so
, which have a very definite sense and meaning."
) We should regard econometrics and mathemat-
al economics critically as bourgeois theoretical
ends and under no circumstances must we give
the integrity and strict unity of the Marxist-
eninist world outlook. We should always remem-
r Lenin's remark about bourgeois scientists:
Ve must not believe a single word of a single pro-
ssor of political economy who is capable of pro-
cing the most valuable works in the field of
ctual and special research, once the question con-
rns the general theory of political economy. For
e latter is as much a partisan science in modern
ciety as is gnosiology." (4)

We know, for example, that while completely
jecting Ernst Mach's idealist philosophy, which
s shattered by Lenin, our scientists at the same
e successfully apply Mach's unit, the well-
own aerodynamic criterion, in supersonic avia-
n. While discarding the bourgeois conceptions
the American economist Leontief, we can suc-
ssfully employ "input-output" analysis, or, to be
re exact, the method of analysis of interindustry
oduction links, all the more so because this meth-
undoubtedly arose under the direct and imme-
te influence of the first Soviet national economic
ances compiled by the Central Statistical Ad-
nistration of the USSR for 1923-1924. We should not shun and be afraid of the term "econometric investigations," if these are properly understood and applied in the conditions of the socialist economy. We have to critically examine the foreign studies in econometrics and mathematical economics, and everything that is useful and valuable in the computing, mathematical apparatus suitable for the study of economic relationships should be made use of in practice in our planned economy.

At the same time we must remember that a hasty and uncritical approach to the study of bourgeois econometrics and mathematical economics can only hinder the fruitful application of mathematical methods in economic research and planning.

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In examining the question of our attitude to econometrics and mathematical economics there inevitably arises another question: will not the application of mathematical methods in economic research and planning lead to the creation of a new and special science? As we know, this problem has been widely discussed in our literature by economists, statisticians, planners and mathematicians.

In meeting this problem it is necessary to clearly distinguish between sciences: general and special (particular), independent and subsidiary, theoretical and applied, broader and narrower. While political economy, statistics and mathematics are independent fundamental general theoretical sciences, the existence of borderline fields between them makes possible the emergence of more particular, special and subsidiary branches of knowledge. Where there is a planned economy, when the scientific principles of planning are already becoming a special branch of knowledge, there are even more grounds for the emergence of other intermediate and subsidiary scientific and academic disciplines. However, these intermediate branches of knowledge cannot be counterposed to the basic sciences, and it is all the more obvious that the special applied scientific disciplines cannot supplant or replace to any degree such a basic science as political economy. We can see no grounds for objecting to the need and inevitability of the emergence of special scientific disciplines in the borderline fields of political economy, planning, mathematics and statistics.

The combined application in any research of various principles and methods, which is usually characteristic of borderline fields involving two or more scientific disciplines, cannot be a purely mechanical one. This combination forms a certain unity, leading to the creation of special or applied scientific disciplines in the respective borderline areas of knowledge. The history of modern science furnishes many such examples. Borderline branches of knowledge are today richest in the so-called "points of growth" and development of science. However, the unification of the different scientific principles by no means signifies that they all stand on an equal footing. In employing mathematical methods in economic studies and planning the fundamental principles of the science of economics must definitely predominate, just as in the application of mathematical methods in natural science the fundamental principles of the sciences of natural history must predominate (as physics, for example). The respective intermediate scientific or academic discipline, therefore, cannot develop apart from the political economy of socialism and form a certain autonomous field of science with respect to it.

On the other hand, it is obvious that there is constantly going on a process of growth of new specialties and new scientific disciplines, the function of which is to serve a new field of practical activity. This applies also to the borderline fields of such sciences as political economy, planning, mathematics and statistics. In particular, it is perfectly obvious that a new specific mathematical apparatus is now being developed, one that meets the conditions and requirements of the science of economics.

This new field as yet has no generally accepted name in our country. However, in the higher educational establishments of the USSR new departments are being opened up to train specialists in this field, economic and mathematical computation laboratories are being organized and special lecture courses are being given in mathematical methods of economic computations, courses in national economic planning, the national economic balance, and so on. The time has therefore come to agree on a generally accepted name for this branch of knowledge. For example, it could be called economic-mathematical methods, or the theory of planning calculations, Soviet econometrics or the application of mathematical methods in economic research and planning.

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The rapid rate of development and the growing scale of the socialist economy require further improvement of economic management, above all in planning the national economy. For national economic planning the perfection of the system of planning calculations is assuming ever greater importance, calculations which have their own specific mathematical character, differing from the one found in technical-economical and other calculations.

Socialist society did not on its emergence receive a ready-made mathematical apparatus to meet the requirements of planning, and it was to meet the needs of planning that a new method, a method of balances, was worked out in the early years of our socialist construction.

On the instructions of the government, the Central Statistical Administration of the USSR in 192
prepared a balance of the national economy of the
USSR for 1923-1924. It was the world's first national economic balance and it included a chessboard balance of inter-branch production relation
ships for 14 branches of industry, four branches
agriculture and four other branches of the nationa
economy. In addition, the balance contained many
material balances of individual means of production and articles of consumption.

In preparing the first control figures of nationa
economic development and the first five-year plan
the balance method was already extensively used,
in particular the method of material balances. T
day hundreds of material balances are prepared b
the planning organizations of the USSR for the pur
pose of general planning (there were 285 in 1959))
and the supply agencies make up thousands of ma
terial balances to ensure industrial enterprises with supplies of materials (in 1959 there were 10,500 such balances).

In the prewar period a new mathematical appar
tus for selecting the optimum production plan wit
in the limits of some particular production comp
began to be developed. (5) This was the beginnin
of the elaboration of a new mathematical apparat
which later was given the name of optimum programming (linear and dynamic programming).

During the Second World War similar mathema
ical methods appeared in the United States in con
nection with the needs of material and technical supply of the Army and Air Force. Research in this field was connected with the work of a group
the US Air Force. It was directed by M. Wood, a
one of his staff, J. Dantzig, developed a new met
of linear programming called the simplex metho
(6) Somewhat earlier (in 1941) E. Hitchcock firs
raised the problem of applying linear programm
in making up a freight traffic plan, but it was not
fully solved.

Today mathematical methods for solving problems arising in the process of economic computa
tions are being intensively worked on in the Sovi
Union and abroad. These labors are of very gre
importance, especially in connection with the us
of electronic computers in planning. Simultaneo
ly, a mathematical apparatus is being worked ou
in the USSR adapted to the needs of national economic and production planning, as well as a theo
of planning computations.

The basis for the theory of planning computati the combined use of three methods, namely, the lance method, the method of modelling national onomic processes, and the method of selecting e optimum variant of a program.

Our planning urgently requires the elaboration sufficiently complex economic models embrac- g the various aspects of the socialist economy. onsiderable difficulties have arisen in the dy- amic modelling of national economic processes. onstruction of dynamic national economic models one of the major specific methods of national onomic planning.

National economic models are based on a system mathematical equations and inequations. The rst national economic models were in Marx's ell known scheme of expanded reproduction and enin's scheme of the marketing of the social prod- t. Marx made the basis of his scheme of ex- nded reproduction the equation of simple repro- ction and the following inequation: the net output department I of social production is greater than e material costs of department II. This scheme, turally, has to be considerably concretized in the udy and planning of the socialist economy.

In the preparation of a national economic model envisage the use of a system of mathematical uations and inequations which characterizes the antitative interconnections among the elements the national economy through, for example, the stem of technological coefficients (coefficients labor expenditures, raw materials, fuel, elec- c power, and so on, and output) or values reflect- g the structure and dynamics of individual branch- of the national economy. In constructing the odel the limiting conditions for the given period e simultaneously determined in mathematical m (limits of capital investment, of available la- r resources, raw and auxiliary material re- urces, and so on). Finally, the national economic ective is determined in the form of characteris- equations (functions), for example — the maxi- m possible volume of consumer goods or ex- rts given one or another structure, minimum penditures of labor or capital investments, the west production costs, and so on, depending on nature of the problem. Of special importance national models in which two objectives are multaneously formulated mathematically (in the m of a dual problem), one of which is expressed the form of a maximum and the other in the m of a minimum of the respective functions (for tance, the minimum labor expenditures, the ximum output of the finished product).

properly constructed economic-mathematical del makes it possible to apply mathematical thods in working with it, in particular to select in this way the optimum variant of a program or plan. What makes the methods of optimum programming especially valuable is that they enable us to avoid direct examination of all the numerous possible variants of the program or plan, making it possible (by proceeding from some initial basic plan) to select the best version of the plan or program by means of a small series of approximations (usually no more than ten). In such a series of approximations we proceed from the objective criteria of the optimum condition (for example, from the minimum cost of production or minimum capital investments, or minimum transport shipments, and so on, depending on the nature of the problem) and apply the established rules of calculation. Moreover, selection of the optimum variant is based on strictly defined concrete conditions (formulated in the form of some combination of technological and structural coefficients as well as given limits) with a view to attaining the economic result fixed in advance (formulated in the form of some criterion of the optimum condition). The selected optimum plan or program is best only for the aggregate of the elements making up the given economic-mathematical model and not for the individual elements of the aggregate. This shows the statistical nature of problems of this kind. Hence, determination of the maximum or minimum in planning and programming calculations has its specific features. The very possibility of finding the extreme values for linear functions is determined by introducing into the problem a series of limiting conditions, in particular the requirement that we limit ourselves to only positive values of the variables.

Today, a number of methods of optimum programming have been worked out, including the simplex method, the method of potentials, the method of objectively conditioned estimates and resolving multipliers, and so on. However, most of them are suitable mainly for solving problems of factory production planning (programming) and do not meet the requirements of national economic planning. In view of this, the chief task of Soviet mathematicians and economists is to hasten the working out of mathematical methods to meet the specific requirements of national economic planning. In particular, it is necessary to step up the development of methods of appropriate planning calculations suitable for our practice of planned price fixing and for determining the amount of socially necessary expenditures of labor.

Besides being based on an appropriate system of mathematical equations and inequations, national economic models take the form of tables representing a consolidated material balance and a national economic balance expressed in value terms.

As mentioned before, planning computations comprise an organic unity of three different methods: the method of balances, the method of mathematical modelling of economic processes, and the method of optimum (linear and dynamic) programming. While each is of considerable importance by itself, their greatest value lies in their synthesis in the form of an emerging theory of planning calculations. In such a synthesis each of the methods undergoes certain changes by virtue of their interaction. For instance, the inter-branch balance of production and distribution thus far does not meet the requirements of a balance of expanded reproduction. (7)

The theory of planning calculations by no means encompasses the diversity of national economic planning, which requires a highly complex system of measures and varied organizational solutions to ensure social progress, higher material and cultural standards of the working people, and the full development of all members of society.

What are the main directions in which the problem of applying mathematical methods in economic research and planning is being worked on in the USSR today?

The main direction of the work is in elaborating a theory of planning calculations and a general mathematical methodology for preparing and directing the fulfillment of an optimum national economic plan. Of chief importance here is the problem of commensurability of social expenditures and results in the socialist economy, and in particular, the creation of a system of planned prices that would meet the requirements of the optimum variant of the program or plan. It is especially important to use mathematical methods in working out such planned economic criteria of profitability as would serve individual state and cooperative enterprises as a guide in fully combining their individual interests with those of the national economy while operating on the cost accounting principle. One of the big problems in this area is the problem of economic effectiveness of capital investments.

The role of mathematical methods in national economic planning by no means ends with the preparation of the plan itself. Of no less importance is their application in the operative guidance of plan fulfillment. Modern methods of machine mathematics make it possible to revise the plan on the basis of the regular use of reports on plan fulfillment. They bring to light in certain cases the need for correcting production targets, planned quotas and planned prices. In particular, the use of various technological and economic norms, of which there are a vast number in our economic practice, is of great importance in national economic and production planning. The use of electronic computing machines makes it possible to rapidly pass from detailed norms to combined norms suitable for branch and national economic planning. The electronic computing office of the State Planning Committee of the USSR has already begun working on the solution of this important and complicated problem.

The next direction in the application of mathematics in economics, an area of work which has it own specific character, is the working out of inter branch and interregional balances of production an distribution of goods (for the national economy as whole and for individual economic areas). The construction of this type of model makes it possib to determine the coefficients of the so-called full expenditures of various kinds (such as labor time in man-hours, power in terms of conventional fuel electric power in kwh., rolled steel in tons, capita expenditures in rubles, and so on). Full expenditures differ from direct expenditures in that they are calculated in terms of the final product (account is taken of the respective expenditures in all the intermediate stages of production). These coefficients of full expenditures make it possible to estimate the consumption fund, the supply of export goods, the composition of the national income in material terms, the accumulation fund, and so on, not only in monetary units but also in full expenditures of labor time or energy, as well as in units of expenditures of particular kinds of imports or materials in short supply.

Inter-branch balances of production and distrib tion prepared for two or more years in a row (pr vided capital investments are included in the chessboard part of the balance) enable us to deter mine the economic effectiveness of capital invest ments by industries with due account taken of the investments in allied spheres of material produc tion. Where the number of plants chosen for this type of inter-branch balance is sufficiently large (400-500) we can determine the expenditures of s cial labor for the more important articles of pro duction in units of labor time, which is of very great importance in planning prices at the level o social value and in analyzing deviations of prices from values.

An important part is played by a third special direction in the application of mathematical meth ods in economic research, namely, the mathemat cal analysis of the scheme of expanded reproduc tion. Such research was begun in the USSR in th 1920's. Through such analysis we can establish, among other things, the connection between the oefficient of growth of the social product and the elative share of department I, the materials and upplies consumed in production, or the interrela- onships between the dynamic and structural char- cteristics of the national economy.

The current and planned balances of the national conomy, which have been compiled in our country or some 35 years now, have enabled us to accumu- ate vast experience in constructing balances. Our urrent and planned balances are based on Marx's cheme of expanded reproduction. However, So- iet economists and mathematicians have not yet eveloped a generally recognized economic- athematical model of socialist expanded reproduc- on based on a fully defined system of mathemati- al equations and inequations that would make it ossible to solve various extreme problems — opti- um problems. Such a model should be based on e fundamental scientific principles of the politi- al economy of socialism, and it should ensure the olution of the dual extreme problem — the mini- um expenditure of social labor and the maximum ossible level of material provisions for the mem- ers of the society in the given conditions.

In this economic-mathematical model of a bal- nce of expanded reproduction, the resolving multi- iers will be the magnitudes of expenditures of ocially necessary labor (in units of labor time), d not the prices deviating from values. In the ven model what should be minimized are the so- ially necessary expenditures of labor on the whole nal social product (the material fund of the nation- income), and not the sum of the prices of "serv- es" of labor, land and capital, as some econo- ists and mathematicians sometimes prefer to do conformity with the conceptions of bourgeois onomics. Modern mathematical methods make it ssible to construct such a model to determine the cially necessary expenditures of labor as the full penditures of labor time in the optimum national onomic plan, a model which ensures solution of e dual problem mentioned above.

A dynamic model of the balance of socialist ex- nded reproduction should at the same time take o account such important features as the planned aracter of the economy, technical progress, in- easing labor productivity and rising real wages. ch a dynamic model will make it possible to de- rmine the optimum ratio of accumulation to con- mption, a ratio ensuring the most rapid rate of velopment of the national economy over a long riod, and the optimum proportions between de- rtments I and II, between the production of the truments of labor, objects of labor and articles consumption.

Soviet economists and mathematicians at the present time are studying the diverse problems of the interdependence among the major national economic indices, such as the coefficient of the growth of the national income, the coefficient of effectiveness of fixed capital, the level of productivity of labor, the relative share of department I of social production, the materials and supplies consumed in social production, and so on. These studies are of great importance.

The third direction is the solution of problems of optimum programming of the work of transport. These problems have a specific character of their own. Preparing models of rational transportation links is closely related to the problem of the rational location of production. Today, in the work of Soviet mathematicians the transportation problem is receiving a more general formulation as a problem of preparing a model of an optimum plan of production and transportation. Transportation problems are of a diverse nature — for instance, the best assignment of planes to particular airlines, the best distribution of the merchant fleet among particular sections of waterways, the optimum exploitation of the different means of transportation for carrying different kinds of goods (of the same type and interchangeable goods), selection of a rational scheme for the movement of empty cars, and so on. In addition to general programming methods, special methods have now been worked out in this field, namely, the method of approximation by provisionally accepted optimum plans, the method of potentials, and so on.

The fourth direction in the application of mathematical methods in economic research and planning is the solution of diverse technical-economic problems. These include deriving an optimum plan for using production capacities (for example, the load of machine tools), rational cutting of industrial materials, the most advantageous location of premises (warehouses, stores, and so on), the optimum composition of chemical and other industrial mixtures, and the determination of the best composition of food items and fodder rations (requiring the least consumption of labor and capital and at the same time the cheapest and most nutritious), and so on. Such problems are being extensively worked on in our country and are being successfully solved.

A special sphere of application of mathematical methods is the solution of diverse problems which regularly arise in current practice — for instance, the elaboration of a program of computations on electronic machines where mass calculations are involved (computing the payroll of large factories or institutions, and so on), the processing of bank documents, documents covering the material supplies of a factory, and so on. It is important to organize the exchange of information concerning the ways and means of solving the various problems that arise and to set up centers that could undertake (perhaps on a contractual basis) the solution of problems coming up in our economic practice.

Finally, a very important field for the employment of mathematical methods in economic work is in the application of the principles of mathematical statistics.

More than half a century ago in the field of statistics it was found necessary to use mathematical methods to formulate the laws of individual economic phenomena and processes in quantitative terms as accurately as possible, and not merely descriptively. At the same time this served as a stimulus to the emergence of a new science, one bordering on mathematics and economic statistics — mathematical statistics.

The possibilities inherent in the separate use of the achievements of economic statistics, mathematical statistics and mathematics proper no longer meet the current needs of the socialist national economy and the requirements of scientific planning. Many complex and economically important national economic calculations today require the application of new methods and new means of computation. Among these, first of all, are problems related to serving the needs of the population on a mass scale by means of the trading network, means of communication, the services of community and public utility enterprises, and so on, for in solving such problems both calculations of the probability type and methods of optimum programming are needed to one extent or another. Problems of this kind cannot be solved without applying the mathematical theory of mass servicing, the theory of fluctuating (migrating) aggregates, without a scientific analysis of the dynamics of the level and structure of consumption ("elasticity" of consumption, for instance).

Various economic problems are arising around us and in the near future more and more such problems will arise. Their solution will require the extensive use of diverse up-to-date mathematical methods.

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Soviet economists and mathematicians are faced today with a number of complex and urgent problems. One of the principal problems demanding immediate attention is the preparation of a model balance of expanded socialist reproduction, a model which will make it possible to solve problems of optimum national economic planning. Our rich experience in preparing current and planned national economic balances will play an important part in its solution, in particular, the inter-branch balance of production and distribution for 1959 prepared by the Central Statistical Administration of the USSR jointly with the Economic Research Institute of the State Planning Committee of the USSR.

The experience of preparing inter-branch balances of production and distribution for the country's individual economic areas should also be extended; for example, the experience of preparing the inter-branch balance for the Mordvinian Autonomous Republic should be applied to the Armenian and Belorussian Republics.

We must undertake the preparation of a planned inter-branch balance of production and distribution for 1961 in the form of a single consolidated material balance and an inter-branch and inter-area balance of the social product in value terms. This will enrich our practice of mathematical analysis of expanded socialist reproduction.

A planned consolidated material balance as well as a planned inter-branch and interregional balance of production and distribution are particularl necessary for solving such organizational national economic problems as the rationalization of inter-branch and interregional production links, the rational organization of specialization and cooperation, as well as the rational location of social production.

Major component parts of the national economic plan include the capital investment plan and the material supply plan. In view of this, the introduction of mathematical methods and of electronic computing machines in the work of central supply agencies has assumed great importance. For this purpose, the flow of information should be studied by the central supply agencies in making up and carrying out concrete plans of material supply. The Computing Center of the State Planning Committee of the USSR has now begun to work out appropriate algorithms and programs suitable for electronic computers (such as those for the planne supply of sheet metal). This work should be broa ened and deepened. As regards the capital investment plan, work should be undertaken in two directions: preparation of a model of material su ply and of the financing of construction projects o a particular type (for instance, housing, transport, factory, farming units), and a model of the optimu distribution of capital construction projects (for example, coal mines and quarries, construction a reconstruction of blast and open-hearth furnaces, rolling mills of a particular type, construction of thermal and hydraulic stations).

In connection with the preparation of a planned consolidated material balance and a planned inter branch balance of production and distribution in alue terms, it will also be possible to solve more eneral problems in the determination of the neces- ary amount and structure of capital investments vith the given volume and structure of the consump- ion fund at the given level of the national income.

It is advisable to prepare annually a coordinated lan of research in the application of mathematical iethods in the economy and in planning so as to ationally utilize all our scientific forces. At the ame time provision should be made for an ex- hange of experiences in the application of mathe- iatical methods in solving individual production nd technical-economic problems arising in the vork of our industrial enterprises.

It is also necessary to compile a list of generally ccepted standard terms and mathematical symbols sed in the application of mathematical methods in oviet economic research and planning (for identi- al concepts used all over the world, the terms and ymbole should be in accord with those universally ecognized in the literature abroad). We should ssue a reference journal on questions dealing with ie use of mathematics and electronic computers n economic research, planning and production prac- ice. It is also advisable for the publishing houses oncerned with foreign literature and special pub- ications to organize the extensive publication (with omprehensive critical introductions) of transla- ons of works on econometrics, mathematical conomics, studies of operations, dynamic and lin- ar programming, and so on.

It is particularly important to take measures for e training of specialists in the use of mathematics d electronic computers in economics, technical- onomic research and planning. In this connec- on, special curricula and programs of courses for iversities and colleges should be worked out. ew mathematics curricula should be worked out for onomics departments and special colleges of onomics so as to sharply raise the level of mathe- atical training of economists.

Leningrad University and the Moscow State Eco- mics Institute now have departments for training specialists in the application of mathematics and the use of electronic computers in economics and planning. It would be advisable to extend this network in the future. It is also necessary to considerably extend the network of laboratories working on problems of economic-mathematical methods and planning calculations both at scientific-research institutes as well as at colleges, and introduce the practice of assigning probationers to work in them.

Scientific discussions should be conducted and special conferences held (at least once in two years) on the application of mathematical methods in economic research and planning. It would be advisable to call a working conference in the fall of 1961 to exchange experiences. A national scientific council on the application of mathematical methods in economic research and planning should be set up in 1960 in the Academy of Sciences of the USSR to coordinate work in this field; scientific workers (economists, mathematicians and statisticians) and representatives of planning agencies and computing centers should be taken on its staff.

This whole system of measures will make it possible to deepen and extend research in the very important sphere of the application of mathematical methods and the use of electronic computers in our planning and economic practice.

Footnotes

(1) See Reminiscences About Marx and Engels, Gospolitizdat, 1956, p. 66 (Russian edition).

(2) Ibid., p. 311.

(3) V. I. Lenin, Collected Works, Vol. III, p. 559 (Russian edition).

(4) V. I. Lenin, Ibid., Vol XIV, p. 328.

(5) See Professor L. V. Kantorovich, Matematicheskie metody organizatsii planirovaniia proizvodstva, Leningrad, 1939.

(6) First published in 1948.

(7) See Primenenie matematiki v ekonomicheskikh issledovaniiak, Sotsekgiz, 1959.

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The Use of Mathematical Methods to Determine the Most Rational Pattern of Agricultural Production

In the light of the decisions of the 21st Congress of the CPSU one of the important tasks of Soviet economic science in the field of agriculture consists in working out in accordance with planned state targets questions of the specialization and combination of branches of production in the collective and state farms.

In determining the most economically advantageous combination of branches of agricultural production in the conditions of a particular farm it is possible to apply mathematical methods, thereby considerably facilitating the determination of the correct pattern of these branches. In order to apply mathematics effectively in planning the combination of branches it is necessary to carry out a thorough and detailed preliminary analysis of the economic features of the farm for the purpose of disclosing all the existing possibilities for raising crop yields and productivity of livestock, for lowering costs of production, etc. The decisive condition for the use of mathematics for these purposes is a clear understanding of the tasks set by Party and government decisions in agriculture, tasks which the farms face in the given period. Without observing these conditions mathematical methods, no matter how perfect, cannot be of benefit in the planning of agricultural production.

The most important indices of the economic effectiveness of the various combinations of branches in the collective and state farms are gross and marketable output per unit of land area, productivity of labor, amount of net income, required capital investment, and others. The best combination is that which produces the maximum output with the minimum expenditure of labor and material resources.

To choose the best combination of branches of production is equivalent in the final analysis to choosing the most rational distribution of productive resources among the various branches of production. This purpose is served by the mathematical methods used in planning.

It is important to emphasize that in planning state and collective farm production it is essentia to be guided at all times by the objective of derivin the maximum gross and marketable output with th minimum expenditure of labor and material resources. Every farm must ensure the delivery to the state of the various products in definite quantities.

In such cases it is also possible to apply mathematics and to be guided in choosing a combinatio of agricultural branches by the size of the net income and other indices. However, before applyin mathematical methods it is necessary to assign t the production of a given product a certain quantit of productive resources. The remaining resourc must be used in the production of other products such a way as to ensure the largest possible net farm income.

In this article we shall examine the application of the method of consecutive improvements in the combinations of branches (the simplex method) to the planning of agricultural production. The hypothetical farm chosen for this study has the foll ing main marketable products: grain (spring wheat and winter rye), sunflower, milk, beef, and hogs (feed crops are not given separately). This list of principal production items is characteristic, specifically, of a number of farms on the rig bank of the Volga in Saratov Region. We assume that the hypothetical farm has a sown area of 5,000 hectares and a labor supply amounting to 25,000 man-days in the spring-summer period a 20,000 man-days in the fall-winter period.

In our example, therefore, we have three types of productive resources and four products (milk and beef are counted as a single livestock produc Of course, in actual situations one would deal wit a greater number of resources and products. Th it is often necessary in actual practice to take in consideration the machinery available, etc. How ever, increasing the number of resources and products does not basically change the nature of the problem (increasing the number of resource and products would complicate calculations and

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* A discussion article.

ake the comprehension of the article more diffiult). Considering the crop rotation system used the area, it is assumed that the proportion of nd under marketable grain crops (spring wheat nd winter rye) does not exceed 75%, and of that nder sunflowers does not exceed 25%of the total own area. It is quite possible, however, that the roportion of land under these crops might be less an the limits indicated.

In determining the output of livestock products er hectare of sown area we have assumed that one ectare of feed crop rotation yields 30 centners of eed units. We assume also that 60 centners of eed units are necessary for a cow with its followg (the proportion of cows in the herd is 40%). One ow with its following gives 30 centners of milk and .5 centners of ~~milk~~ meat. Therefore, one hectare of own area can give 15 centners of milk and 1.25 centners of meat. The annual expenditure of labor per cow with its following (not counting the production of feed) is assumed to be 44 man-days. On a per hectare basis this amounts to 22 man-days (10 man-days in the spring-summer period and 12 in the fall-winter period). Labor expenditure per hectare of feed crops equals 3 man-days and is assigned to the spring-summer period. Similar calculations have been made for hogs. To facilitate calculations all the labor needed for the production of crops has been allocated to the spring-summer period (April-September).

Based upon the planned crop yields, livestock productivity, labor requirements, and costs of production of individual products, the data needed in drawing up production plans are as follows (see Table 1):

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Table 1

Product	Labor requirements per hectare of sown area (man-days)		Output per hectare of sown area (in centners)	Value of output in delivery prices per hectare (in rubles)	Expenses per hectare of sown area (rubles)	Net income per hectare of sown area (rubles)
	in spring-summer period (April-Sept.)	in fall-winter period (Oct.-March)				
Grain	2	—	14	700	400	300
Sunflowers	66	—	12	840	490	350
Livestock products	13	12	$\frac{1.25^*}{15}$	2,400	1,700	700
Hogs	19	10	5	3,650	3,000	650

* Meat above, milk below line.

Now we must determine the most effective comation of production of these types of output.

At first glance it would seem that the farm should ecialize exclusively in the production of milk and ef. This conclusion, however, is premature. If entire manpower at the disposal of the farm in spring-summer period were utilized, the farm ld use 1,923 hectares of sown area $\left(\frac{25{,}000}{\cancel{12}\ 13}\right)$ for production of milk and beef. The manpower ilable in the fall-winter period makes it possible use 1,667 hectares $\left(\frac{20{,}000}{12}\right)$ for the same purpose. e limiting factor in this case, therefore, is the n power available in the fall-winter period.

Thus, for the production of milk and beef it is possible to use not more than 1,667 hectares, which gives a net income of 1,166,900 rubles (700 x 1,667). Similar simple calculations show that specialization in the production of hogs gives a larger net income. The limiting factor for hogs is again manpower in the fall-winter period $\left(\frac{20{,}000}{10}\right)$ $\left(\frac{25{,}000}{9}\right)$ It permits the use of 2,000 hectares for pork production and the net income becomes 1,300,000 rubles, which is higher than the maximum net income obtained if the entire manpower in the fall-winter period were to be used for the production of milk and beef. Thus, in determining the best pattern for the branches of agricultural production mathematical methods, specifically linear programming methods, may be of substantial aid to the planners.

Let us first give a mathematical interpretation of the problem at hand. We indicate the amount of grain to be produced by X_1, sunflowers by X_2, milk and beef by X_3, and hogs by X_4. Since the unit used is the amount of the various products produced per hectare of sown area, X_1, X_2, X_3 and X_4 indicate the corresponding amounts of sown area used in the production of the various types of output. One hectare of grain yields, as we have assumed, a net income of 300 rubles. Therefore, the total net income from grain is 300 X_1; from sunflowers, cattle, and hogs it is respectively 350 X_2, 700 X_3, and 650 X_4.

The problem consists in finding the values of X_1, X_2, X_3, and X_4 for which the total net farm income is at a maximum. Moreover, the following conditions must be observed:

$$X_1 + X_2 + X_3 + X_4 \leqq 5{,}000 \qquad X_1 < 3{,}750$$
$$2X_1 + 6X_2 + 13X_3 + 9X_4 \leq 25{,}000 \qquad X_2 < 1{,}250$$
$$12X_3 + 10X_4 < 20{,}000$$

The first inequality states that the total sown area utilized for the production of all types of products must not exceed the 5,000 hectares which are at the disposal of the farm. The left-hand part of the second inequality represents the total manpower utilized in the spring-summer period. It must not exceed the total manpower available on the farm during this period. The third inequality is similar, except that it refers to manpower used in the fall-winter period. The fourth inequality states that under no circumstance should the area under grain exceed 3,750 hectares $(5{,}000 \times \frac{75}{100})$ which is the assumed "limit" for grain crops. The last inequality means the same in relation to sunflowers. Its sown area must not exceed 1,250 hectares $(5{,}000 \times \frac{25}{100})$.

For purposes of subsequent calculations it is necessary to transform the above inequalities into equations. This is accomplished by the introduction into each inequality of an additional variable. In the first inequality we introduce X_5, in the second — X_6, in the third — X_7, in the fourth — X_8, and in the fifth — X_9. As a result, we obtain the following equations:

$$\begin{aligned} X_1 + X_2 + X_3 + X_4 + X_5 &= 5{,}000 \\ 2X_1 + 6X_2 + 13X_3 + 9X_4 + X_6 &= 25{,}000 \\ 12X_3 + 10X_4 + X_7 &= 20{,}000 \\ X_1 + X_8 &= 3{,}750 \\ X_2 + X_9 &= 1{,}250 \end{aligned}$$

Quantity X_5 represents the land area left unsown (after the optimum combination of the variou branches is ascertained it is possible that because of a shortage of manpower a portion of the land area is left unutilized). Quantity X_6 represents the manpower left unutilized in the spring-summe period, and quantity X_7 is the manpower left unutilized in the fall-winter period. Quantity X_8 represents the area which in the given crop rotation system should be sown to grain but which actually is used for other purposes. Quantity X_9 has a similar meaning, but in respect to sunflowers. One should note that the units used for the additio al variables are not the same. We now rewrite the above equations so as to place the same variables under each other.

$$\begin{array}{lllllllll} X_1 + & X_2 + & X_3 + & X_4 + X_5 & & & & & = 5{,}000 \\ 2X_1 + & 6X_2 + & 13X_3 + & 9X_4 & + X_6 & & & & = 25{,}000 \\ & & 12X_3 + & 10X_4 & & + X_7 & & & = 20{,}000 \\ X_1 + & & & & & & + X_8 & & = 3{,}750 \\ & X_2 + & & & & & & + X_9 & = 1{,}250 \end{array}$$

After this begins the most important stage in th calculations, based as it is on methods worked ou by higher mathematics.

We place in one column all the coefficients appearing before X_1 (where this variable is absent, we write 0):

$$\begin{array}{c} 1 \\ 2 \\ 0 \\ 1 \\ 0 \end{array}$$

This column of figures arranged in a given ord represents, on the one hand, the productive resources which are needed in the production of grain on one hectare (such are the figures 1, 2, 0) and on the other, the limitations imposed on grai production by the crop rotation system in use. In other words, this column of figures (in mathemat ics it is called a vector) characterizes the conditions of grain production on one hectare of land.

We indicate this vector by P_1. The vectors characterizing the conditions of production of su flower, milk and beef, and hogs on one hectare are indicated by:

$$\begin{array}{c} 1 \\ 6 \\ 0 \\ 0 \\ 1 \end{array} - P_2 \qquad \begin{array}{c} 1 \\ 13 \\ 12 \\ 0 \\ 0 \end{array} - P_3 \qquad \begin{array}{c} 1 \\ 9 \\ 10 \\ 0 \\ 0 \end{array} - P_4$$

In the same manner we deal with the coefficien of the additional variables characterizing the unused resources:

$$\begin{array}{c}1\\0\\0\\0\\0\end{array} = P_5 \quad \begin{array}{c}0\\1\\0\\0\\0\end{array} = P_6 \quad \begin{array}{c}0\\0\\1\\0\\0\end{array} = P_7 \quad \begin{array}{c}0\\0\\0\\1\\0\end{array} = P_8 \quad \begin{array}{c}0\\0\\0\\0\\1\end{array} = P_9$$

We then draw up Table 2, which is the point of departure for subsequent computations (see Table 2).

Let us consider the economic meaning of this table. First, let us examine the columns on the right-hand side of the table. The column of figures characterizing the conditions of grain production, vector P_1, may be represented as the sum of the products of the vectors characterizing the unused resources by the elements making up the given vector:

$$P_1 = 1P_5 + 2P_6 + OP_7 + 1P_8 + OP_9 \text{ or}$$

$$\begin{array}{c}1\\2\\0\\1\\0\end{array} = 1x \begin{array}{c}1\\0\\0\\0\\0\end{array} + 2x \begin{array}{c}0\\1\\0\\0\\0\end{array} + 0x \begin{array}{c}0\\0\\1\\0\\0\end{array} + 1x \begin{array}{c}0\\0\\0\\1\\0\end{array} + 0x \begin{array}{c}0\\0\\0\\0\\1\end{array}$$

Table 2

P_5	P_6	P_7	P_8	P_9	P_1	P_2	P_3	P_4
1	0	0	0	0	1	1	1	1
0	1	0	0	0	2	6	13	9
0	0	1	0	0	0	0	12	10
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	1	0	0

In the same manner we express through P_5, P_6, P_7, P_8, P_9 the vectors characterizing the produc-ion of sunflower, milk and beef, and hogs:

$$P_2 = 1P_5 + 6P_6 + OP_7 + OP_8 + 1P_9$$

$$P_3 = 1P_5 + 13P_6 + 12P_7 + OP_8 + OP_9$$

$$P_4 = 1P_5 + 9P_6 + 10P_7 + OP_8 + OP_9$$

The vectors P_5, P_6, P_7, P_8, and P_9 in this case re the basic ones, i.e., we represent the other ectors through them.

We now turn directly to the determination of the ational combination of the various branches of gricultural production. In choosing the most ad-antageous combination we shall strive to ensure, n the one hand, the maximum utilization of all roductive resources and, on the other, the distri-ution of these resources in the first instance mong thóse branches which yield the largest net come.

Let us assume that the first combination is one hich yields no production. We introduce one ore vector into the calculations:

$$P_o = \begin{array}{r}5,000\\25,000\\20,000\\3,750\\1,250\end{array}$$

This vector characterizes all the resources available on the farm. In the first combination all resources are left unused. This combination is expressed by the following equation:

$$P_o = 5,000P_5 + 25,000P_6 + 20,000P_7 + 3,750P_8 + 1,250P_9$$

We see from Table 1 that the largest net income per 100 hectares is produced by large horned cattle. As we have already seen, the limiting factor for large horned cattle is manpower in the fall-winter period, which permits the use of not more than 1,667 hectares.

From Table 2 it is apparent that $P_3 = 1P_5 + 13P_6 + 12P_7 + OP_8 + OP_9$ (the last two items will be omitted from the calculations).

Now we introduce into the equation characterizing the first combination of branches the expression $X_3 (P_3 - 1P_5 - 13P_6 - 12P_7)$. It is clear that this is equal to zero. We then have:

$$P_o = 5,000P_5 + 25,000P_6 + 20,000P_7 + 3,750P_8 + 1,250P_9 + X_3 (P_3 - 1P_5 - 13P_6 - 12P_7).$$

We open the brackets and make some simple transformations:

$$P_o = (5{,}000 - X_3)P_5 + (25{,}000 - 13X_3)P_6$$
$$+ (20{,}000 - 12X_3)P_7 + 3{,}750P_8 + 1{,}250P_9 + X_3P_3.$$

We evaluate the coefficients in brackets $(5{,}000 - X_3)$, $(25{,}000 - 13X_3)$ and $(20{,}000 - 12X_3)$. The maximum value of X_3 is $X_3 = \frac{20{,}000}{12} = 1{,}667$. For this value of X_3 the coefficient before P_7 becomes zero, the one before P_5 becomes $5{,}000 - 1{,}667 = 3{,}333$, and the one before P_6 becomes $25{,}000 - (1{,}667 \times 13) = 3{,}329$.

As a result, we have the following equation:

$$P_o = 3{,}333P_5 + 3{,}329P_6 + OP_7 + 3{,}750P_8$$
$$+ 1{,}250P_9 + 1{,}667P_3.$$

If we now consider the variables by which we represent the number of hectares used in the production of each product and the quantity of unutilized resources, we have

$$X_1 = 0;\ X_2 = 0;\ X_3 = 1{,}667;\ X_4 = 0;\ X_5 = 3{,}333;$$
$$X_6 = 3{,}329;\ X_7 = 0;\ X_8 = 3{,}750;\ X_9 = 1{,}250.$$

The second combination of branches produces monetary receipts of 1,166,900 rubles (1,667 hectares x 700 rubles).

Now we must try to improve on the second combination.

To accomplish this we express all the vectors characterizing the conditions of production of the various products and the unutilized resources through the five vectors which are included in the second combination, i.e., P_5, P_6, P_8, P_9, and P_3.

First, we must express through a new basis vec tor P_7, which has been eliminated from the old basis (because the entire manpower in the fall-winter period has been utilized in the production o milk and beef). As we have previously seen, vector P_3, introduced into the second combination (milk and beef), may be represented as follows: $P_3 = 1P_5 + 13P_6 + 12P_7 + OP_8 + OP_9$. From this:

$$P_7 = \frac{1}{12}P_3 - \frac{1}{12}P_5 - \frac{13}{12}P_6 = OP_8 = OP_9$$

(The last two items are omitted from subsequent calculations). Now we can express all the vectors through a new basis. Let us consider, for instance, vector P_4. As may be seen from Table 2:

$$P_4 = 1P_5 + 9P_6 + 10P_7 + OP_8 + OP_9$$

We substitute for P_7 its new value:

$$P_4 = 1P_5 + 9P_6 + 10\left(\frac{1}{12}P_3 - \frac{1}{12}P_5 - \frac{13}{12}P_6\right) = \frac{1}{6}P_5 - \frac{11}{6}P_6 + \frac{5}{6}P_3$$

The new equation is interpreted in economic terms as follows: for the production of hogs per hectare of sown area it is necessary to draw upon the resources needed in the production of milk an beef to the extent of 5/6 hectare (5/6 P_3) and in addition to use 1/6 hectare of the sown area (1/6 P_5). At the same time 11/6 man-days in the spring-summer period are released (11/6 P_6).

In the same way we express all the other vectors through the new basis (see Table 3):

Table 3

Di			0	0	0	0	0	300	350	700	650
Di	Pi	P_o	P_5	P_6	P_7	P_8	P_9	P_1	P_2	P_3	P_4
0	P_5	3,333	1	0	- 1/12	0	0	1	1	0	1/6
0	P_6	3,329	0	1	-13/12	0	0	2	6	0	-11/6
0	P_8	3,750	0	0	0	1	0	1	0	0	0
0	P_9	1,250	0	0	0	0	1	0	1	0	0
700	P_3	1,667	0	0	1/12	0	0	0	0	1	5/6
Dj Dj-Di		1,166,900	0 0	0 0	58 58	0 0	0 0	0 -300	0 -350	700 0	583 -67

Let us first consider the columns of this table. Here each vector is expressed through vectors P_5, P_6, P_8, P_9, and P_3, placed in column Pi; vector P_1 is expressed through the equation $P_1 = 1P_5 + 2P_6 + 1P_8 + 0P_9 + 0P_3$; and vector P_2 through the equation $P_2 = 1P_5 + 6P_6 + 0P_8 + 1P_9 + 0P_3$.

Di, read across the table, represents the amount of net income produced by each product per hectare of land; read vertically, it indicates the amount of net income produced by the products included in the basis, i.e., in the second combination of branches (in this case, P_3, beef and milk, produces a net income of 700 rubles, while the unutilized resources, naturally, produce no income).

Quantity Dj is more complex. It shows the net income yielded by the products which should no longer be produced in order to produce the given product instead.

Let us consider, for example, hogs. As we have seen, in order to produce hogs it is necessary to forego, per hectare of land, the production of 5/6 of the quantity of milk and beef produced per hectare of sown area, to utilize an additional 1/6 hectare of sown area and release 11/6 man-days in the spring-summer period, i.e., $P_4 = 1/6P_5 -$ $1/6P_6 + 5/6P_3$.

Let us now determine the net income lost per hectare of land as a result of the diversion of resources to the production of hogs. Unutilized resources P_5 and P_6 produce no income, while milk and beef bring 700 rubles per hectare. Therefore, the total loss of net income is: $0 \times 1/6 - 0 \times 11/6$ $+ 700 \times 5/6 = 583$ rubles. It is this figure that we find in row Dj and column P_4.

The production of grain and sunflower does not necessitate a diminution in the production of milk and beef. Therefore, in row Dj under P_1 and P_2 we find zeros. Indeed, $P_1 = 1P_5 + 2P_6 + 1P_8$ $+ 1P_8 + 0P_9 + 0P_3$. Let us substitute for P_5, P_6, P_8, P_9, and P_3 the corresponding net income: $\times 0 + 2 \times 0 + 1 \times 0 + 0 \times 0 + 0 \times 700 = 0$.

Let us now explain the figure 58 which appears at the intersection of row Dj and column P_7. First, we consider the meaning of the equation $P_7 =$ $1/12P_5 - 13/12P_6 + 0P_8 + 0P_9 + 1/12P_3$. With the entire manpower in the fall-winter period (P_7) utilized in caring for cattle, the release of one man-day in this period leads to a diminution in the production of milk and beef by 1/12 per hectare. At the same time 1/12 hectare of sown area and 13/12 man-days in the spring-summer period are also released. Including in the equation the net income corresponding to each vector P_5, P_6, P_8, P_9, and $_3$, we obtain $- 1/12 \times 0 - 13/12 \times 0 + 0 \times 0 + 0 \times 0$ $1/12 \times 700 = 700/12 = 58$.

Therefore, the release of one man-day in the fall-winter period reduces the net income by 58 rubles.

We now consider the figures in the row Dj - Di. They indicate whether the net income received from each product per hectare is greater or smaller than the income which would be lost due to the decrease in the production of the products included in the basis, i.e., in this case, cattle products. The difference between the values (Dj - Di) for the unutilized resources (P_5, P_6, P_8, P_9) is 0. The release of one man-day in the fall-winter period (P_7) causes a loss of net income which could be received from the production of P_3 products equal to 58 rubles. The production of grain does not cause a decrease in the production of milk and meat or in the income received from these products. Therefore, the introduction of grain permits the farm to receive an additional income of 300 rubles per hectare. A similar situation is found in the case of sunflowers. Their production ensures an additional income of 350 rubles per hectare.

Next we consider hogs. Their production would bring 650 rubles per hectare, while the loss of income this entails would amount to 583 rubles. Therefore, this gives an additional income of 67 rubles per hectare. Thus, it is economically advantageous to produce all three items — sunflowers, grain, and pork.

Let us draw up a new, the third combination of branches. The largest additional income would be received from the introduction of sunflower production. We include in the basis vector P_2, which characterizes the resources needed for sunflower production per hectare. Again we use the procedure outlined above. As we saw, the second combination of branches is expressed through the following equation:

$$P_0 = 3,333P_5 + 3,329P_6 + 3,750P_8 + 1,250P_9 + 1,667P_3.$$

From Table 3 we see that $P_2 = 1P_5 + 6P_6 + 0P_8 + 1P_9 + 0P_3$. Then:

$$P_0 = 3,333P_5 + 3,329P_6 + 3,750P_8 + 1,250P_9 + 1,667P_3 + X_2\,(P_2 - P_5 - 6P_6 - 1P_9);$$

$$P_0 = (3,333 - X_2)\,P_5 + (3,329 - 6X_2)\,P_6 + 1,667P_3 + 3,750P_8 + (1,250 - X_2)P_9 + X_2P_2.$$

The coefficient of P_6 is equated to 0 (had we done so with the coefficient of P_5, the coefficients of P_6 and P_9 would have been negative, etc.): $3,329 - 6X_2 = 0$; $X_2 = \frac{3,329}{6} = 555$. Then:

$$P_0 = 2,778P_5 + 1,667P_3 + 555P_2 + 3,750P_8 + 695P_9. \quad (1)$$

Thus, the third combination shows the farm should use 1,667 hectares and the corresponding manpower for the production of beef and milk, and 555 hectares for the production of sunflowers. The entire manpower is thus utilized, but 2,778 hectares of land remain unused. Moreover, the farm does not use its "limits" of grain and sunflowers. The crop rotation system permits the use of 3,750 hectares under wheat and rye and another 695 hectares under sunflowers. With this combination of branches the net income received is: (0 x 2,778) + (350 x 555) + (700 x 1,667) + (0 x 3,750) + (0 x 695)= 1,361,150 rubles. This income is larger than that of the second combination by 194,250 rubles.

It is now necessary to express all the vectors through the new basis consisting of P_5, P_6, P_8, P_9, and P_2. In order to do this it is first necessary to express vector P_6 in the new basis; it was in the old basis but not in the new.

From Table 3 we see that $P_2 = 1P_5 + 6P_6 + 0P_8 + 1P_9 + 0P_3$. Therefore, $P_6 = 1/6P_2 - 1/6P_5 - 1/6P_9$ (vectors with 0 are omitted). Now we express all the vectors through the new basis, i.e., through the products and unutilized resources which enter into the new combination of branches. Consider, for instance, vector P_1. From Table 3 we see that $P_1 = 1P_5 + 2P_6 + 1P_8$; we substitute for P_6 the expression $1/6P_2 - 1/6P_5 - 1/6P_9$ and obtain:

$$P_1 = 1P_5 + \frac{1}{3}P_2 - \frac{1}{3}P_5 - \frac{1}{3}P_9 + 1P_8 = \frac{2}{3}P_5 + \frac{1}{3}P_2 + 1P_8 - \frac{1}{3}P_9.$$

The economic meaning of this equation is as follows: the production of grain on one hectare requires the same resources as the production of sur flowers on 1/3 hectare plus 2/3 hectare of sown area. The "limit" for grain is thus reduced by one hectare and the unused "limit" for sunflowers is increased by 1/3 hectare.

In the same way we express all the other vectors through the new basis (see Table 4).

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Table 4

			0	0	0	0	0	300	350	700	650
Di	Pi	P_o	P_5	P_6	P_7	P_8	P_9	P_1	P_2	P_3	P_4
0	P_5	2,778	1	$-\frac{1}{6}$	7/72	0	0	2/3	0	0	17/36
0	P_8	3,750	0	0	0	1	0	1	0	0	0
0	P_9	695	0	$-\frac{1}{6}$	$\frac{13}{72}$	0	1	-1/3	0	0	11/36
700	P_3	1,667	0	0	1/12	0	0	0	0	1	5/6
350	P_2	555	0	1/6	$-\frac{13}{72}$	0	0	1/3	1	0	-11/36
Dj		1,361,150	0	58	4.8	0	0	117	350	700	475
Dj-Di			0	58	4.8	0	0	-183	0	0	-175

An analysis of Table 4 shows that it is advisable to introduce grain and hogs into production. Production of grain on one hectare would decrease the net income received from sunflowers by 117 rubles:

$$(0 \times \frac{2}{3} + 0 \times 1 - 0 \times \frac{1}{3} + 700 \times 0 + 350 \times \frac{1}{3} = 117).$$

On the other hand, the production of grain yields a net income of 300 rubles per hectare. Therefore, the net gain is 183 rubles (300 - 117). The situation is similar with hogs.

Therefore, in order to improve the third combination we again introduce the production of that product which yields the largest additional income. As we see from Table 3, that product is grain. Using the usual procedure, we obtain a fourth com bination of branches which is characterized by the equation:

$$P_o = 1{,}665P_1 + 1{,}667P_3 + 1{,}668P_5 + 2{,}085P_8 + 1{,}250P_9.$$

It will give a net income of 1,666,400 rubles, which is greater than that of the previous combina tion by 305,250 rubles.

Included in the equation for the fourth combination of branches are grain (P_1), milk and beef (P_3), own area (P_5), the unused "limit" for grain (P_8) nd the "limit" for sunflowers (P_9). We express all the vectors through the new basis (see Table 5):

Table 5

			0	0	0	0	0	300	350	700	650
Di	Pi	P_o	P_5	P_6	P_7	P_8	P_9	P_1	P_2	P_3	P_4
0	P_5	1,668	1	-½	11/24	0	0	0	-2	0	13/12
0	P_8	2,085	0	-½	13/24	1	0	0	-3	0	11/12
0	P_9	1,250	0	0	0	0	1	0	1	0	0
300	P_1	1,665	0	½	-13/24	0	0	1	3	0	-11/12
700	P_3	1,667	0	0	1/12	0	0	0	0	1	5/6
Dj		1,666,400	0	150	-104	0	0	0	900	700	308
Dj-Di			0	150	-104	0	0	0	650	0	-342

As may be seen from Table 5, further improve- ent in the combination of enterprises would be chieved by the introduction of hog production. In- eed, hog production per hectare would call forth e diversion of resources from the production of e products included in the fourth combination, hich would diminish the income from these prod- ts by 308 rubles. But hog production yields an lditional income of 650 rubles per hectare. herefore, hog production gives an additional in- me of 342 rubles per hectare.

We draw up an equation characterizing the fifth combination of branches:

$$P_o = 3,076P_1 + 384P_3 + 1,539P_4 + 674P_8 + 1,250P_9.$$

According to this combination the farm, together with the corresponding manpower, utilizes 3,076 hectares for grain, 384 hectares for the production of milk and beef, and 1,539 hectares for hog production. The net income increases to 2,191,950 rubles.

Table 6

			0	0	0	0	0	300	350	700	650
Di	Pi	P_o	P_5	P_6	P_7	P_8	P_9	P_1	P_2	P_3	P_4
0	P_8	674	-11/13	-1/13	2/13	1	0	0	-17/13	0	0
0	P_9	1,250	0	0	0	0	1	0	1	0	0
300	P_1	3,076	11/13	1/13	- 2/13	0	0	1	17/13	0	0
700	P_3	384	-10/13	5/13	- 7/26	0	0	0	20/13	1	0
650	P_4	1,539	12/13	-6/13	11/26	0	0	0	-24/13	0	1
Dj		2,101,950	315	-8	40	0	0	300	269	700	650
Dj-Di			315	-8	40	0	0	0	-81	0	0

An analysis of Table 6 shows that a further improvement in the pattern of production is possible by the inclusion of an additional income of 81 rubles. We introduce sunflowers again (they were introduced before but in a different combination of products). The sixth combination of products is characterized by the following equation:

$$P_o = 2{,}750P_1 + 250P_2 + 2{,}000P_4 + 1{,}000P_8 + 1{,}000P_9$$ (2

It will ensure the receipt of a net income amounting to 2,212,500 rubles. Is it possible to improve upon this combination? To answer this question we construct a new vector table (Table 7):

Table 7

			0	0	0	0	0	300	750	700	650
Di	Pi	P_o	P_5	P_6	P_7	P_8	P_9	P_1	P_2	P_3	P_4
0 0 300 350 650	P_8 P_9 P_1 P_2 P_4	1,000 1,000 2,750 250 2,000	-3/2 1/2 3/2 -1/2 0	1/4 -1/4 -1/4 1/4 0	-39/520 91/520 39/520 -91/520 1/10	1 0 0 0 0	0 1 0 0 0	0 0 1 0 0	0 0 0 1 0	17/20 -13/20 -17/20 13/20 6/5	0 0 0 0 1
Dj		2,262,500	275	12.5	26	0	0	300	350	807.5	650
Dj-Di			275	12.5	26	0	0	0	0	107.5	0

An examination of this table shows that no change in the pattern of production would increase net income. This is evident from the fact that in the last row of the table all the values are positive. Thus, the introduction of milk and beef into the production program would decrease net income by 807.5 rubles per hectare, while these products bring a net income of only 700 rubles per hectare. The sixth combination of enterprises is, therefore, the optimum combination. We then have: $X_1 = 2{,}750$; $X_2 = 250$; $X_3 = 0$; $X_4 = 2{,}000$; $X_5 = 0$; $X_6 = 0$; $X_7 = 0$; $X_8 = 1{,}000$; $X_9 = 1{,}000$.

This means that the farm should use 2,750 hectares of its crop area to grow grain, 250 hectares for sunflowers, and 2,000 hectares to produce fodder for its hogs. This combination ensures the complete utilization of the farm's production resources.

In conclusion, it is pertinent to point out that planning in a collective farm or state farm should be divided into three stages. During the first stage a thorough analysis is made of all the possibilities for increasing crop yields and livestock productivity and decreasing production costs. The analysis should be based upon the latest achievements of agronomy and animal husbandry science and progressive farm practices.

At the second stage mathematical computations are performed with the objective of ensuring the most effective utilization of the farm's resources.

At the third stage the results obtained are reviewed, with due consideration for those peculiarities of the farm which had not been sufficiently taken into account in the mathematical calculations.

This signifies that the results obtained with the aid of the mathematical computations outlined above should in no way be regarded as final. They should serve only as a basis for drawing up the final plan for the combination of branches in the farm. Mathematical methods give no ready-made prescriptions suitable for all farms, but merely conclusions which may be applied only to a particular concrete farm.

The mathematical method of planning outlined in this article is far from perfect. Mathematics and economics have actually only begun to work out such methods. However, it is clear that the necessity for further raising the quality of plannin work demands increased use of mathematics in economics.

The socialist economic system opens up broad prospects for applying mathematical methods in production planning.

Footnotes

(1) Some figures are rounded.
(2) The values of coefficients are approximate.

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. BIRMAN:

Calculation of an Optimum Scheme of Transportation of Interchangeable Products

Rational transportation of major goods like fuel, certain kinds of building materials, grain, and others, is one of the chief problems in improving nter-branch and territorial links in the country's economy. These goods are produced in many localities and are consumed practically everywhere. Since transportation costs account for a considerable portion of the costs of these materials, free place of consumption, it is of considerable importance to ascertain those ties between suppliers and consumers which would involve minimum transportation costs. Such estimates are especially important in validating freight transportation plans.

Mathematically, this problem is a particular case of the so-called extreme problems. Given a linear relationship between magnitudes, these problems are solved through the linear programming techniques evolved by Soviet and foreign scholars. Because of the large number of interrelated calculations involved in the use of these methods, they have acquired practical importance only after the advent of electronic computers, with their great “memory” and high speed of calculation.

Abroad, the transportation problem in recent years has been tackled by the simplex method or the so-called distribution method. Solving it through the use of these methods of linear programming on electronic computers involves a number of technical difficulties. Nevertheless, because of the highly effective nature of these calculations they have been used abroad on an ever increasing scale.

A. L. Lur'e, Candidate of Economic Science, has proposed a method of solving these problems which he named the resolving components method. (1) At the computation center of the USSR Academy of Sciences the resolving components method was used, for example, to calculate an optimum plan for the transportation of gravel throughout Moscow. (2) This calculation determined the most rational variant for assigning suppliers to consumers from the point of view of minimizing the distances of shipments. Since within city limits sand is carried chiefly by motor transport, shipments over the shortest distances involve the lowest transportation costs.

Let us consider very briefly the essence of the resolving components method. Suppose we have the following data on suppliers and consumers:

Table 1

Suppliers	Volume of production in physical units	Consumers and Amount of Demand			
		B_1 4,600	B_2 8,000	B_3 1,240	B_4 3,920
A_1	5,600	10	6* 5,600	8	16
A_2	10,160	10	8	12 0	18
A_3	2,000	8* 2,000	14	6* 0	6* 0

The two left-hand columns list the suppliers and their possible volumes of delivery. The two upper rows indicate the consumers and their respective demands. The sum total of supply and of demand coincide in the table.

Each square of the table is divided into two triangles. The upper triangles indicate the distances between the points where the suppliers are located and those where the consumers are located. Thus, the distance between supplier A_1 and consumer B_2 equals six units, as is indicated in the upper triangle of the respective square. In each column the shortest distance between one of the suppliers and the given consumer is designated by an asterisk. In the first column this distance amounts to 8, in the second to 6, etc. The lower sections of the squares indicate how much output can be delivered by the supplier to the consumer.

If the distribution of deliveries is made only over the shortest distances, i.e., in the squares which are designated by asterisks, as is done in the table, the consumers' demand will not be fully met. In our example consumers B_1 and B_2 will receive only some of the products they require while consumers B_3 and B_4 will receive no products at all. Nor are the respective capacities of the suppliers exhausted.

Since the deliveries corresponding to the shortest distances do not satisfy the conditions of the problem, the best of the other possible versions are tried one after another; each time it is checked whether the demand of all consumers is met.

To increase the total volume of deliveries the distances have to be lengthened for those rows in which the volume of deliveries in a given distribution pattern proved to be insufficient to meet the consumer's demand. As a result, the minimum distances are increased up to the level at which another asterisk appears in a column, with another distribution pattern resulting in the total volume of deliveries increasing as compared with the previous distribution pattern. A number of such consecutive operations increasing the total volume of deliveries (the number of operations depending on the number of suppliers and consumers) leads to the final variant in which all productive capacities are exhausted and all demands fully met. (3)

In the table below the final result for our example is shown.

Table 2

Suppliers	Volume of production in physical units	Consumers and Amount of Demand			
		B_1	B_2	B_3	B_4
		4,600	8,000	1,240	3,920
A_1	5,600	12	8* 4,360	10* 1,240	18
A_2	10,160	10* 4,600	8* 3,640	12	18* 1,920
A_3	2,000	20	26	18	18* 2,000

It is noteworthy that the asterisks have shifted in the final result. Thus, the asterisk corresponding to the shortest distance in the first column of Table 1 was in the third line. In Table 2 the asterisk corresponding to the shortest distance to consumer B_1 is in the second line. This shows once again that the simplest way of calculation is not always the true one and that special calculating methods are often required to obtain the optimum results which meet the conditions of a problem.

An essential drawback of the current methods of solving transportation problems is that they apply to the shipments of only one product.

Yet the calculations for one product can have a very limited range of application, since, with few exceptions, in economic reality we deal with interchangeable products or interchangeable types of the same product.

Take cement, for example. In many cases, it can be replaced by other materials. Masonry mortar can be made both of cement and lime. Reinforced concrete products manufactured with cement can replace bricks or some other building materials. Cement, for its part, is available in several forms: Portland cement, sulfate-resistant cement, etc. Besides, nearly all kinds of cement can be classified from the viewpoint of durability, each class indicated by a special cement grade. Most kinds and grades are interchangeable. Thus, concrete can be produced from Portland cement No. 300, 400, 500 and 600. Slag-cement, trass cement and Portland cement of various grades are all used for masonry mortar.

The ratios in which some products can be replaced by others or some kinds of products by other kinds can vary widely, or, at any rate, are rarely equal to unity. Therefore, the calculation of the optimum transportation plan for all interchangeable products as a whole, without differentiating them, or for each separate product (or a kind of product) without allowances for interchangeability, will not yield the desired results.

If, for example, calculations are made for the shipments of all cement produced in the country, without subdividing it into different kinds and grades, the result may be the deliveries of tamped cement to prefabricated reinforced concrete plants and the deliveries of conventional Portland cement for the construction of hydro-structures in an excessively powerful medium. Naturally, however, tamped cement cannot be employed at prefabricated reinforced concrete plants and sulfate-resistant cement is needed for the above-mentioned hydro-structures. If, on the other hand, calculations were made for the shipments of some individual product, Portland cement 400, for example, we would overlook economically desirable shipments of other kinds and grades.

Similar problems arise in determining the optimum transportation plan for energy fuel, timber, building and many other materials. Thus, numerous grades of coal require that we consider the possibilities of different consumers using coal of different grades, as well as the ratios according to which one grade can be replaced by another (in those cases where this substitution is possible). At the same time, in drawing up the optimum plan for coal transportation, the shipment and consumption of oil, gas and peat must also be taken into account.

If it is possible to interchange two or more varieties of a product, some needs may be satisfied by one or several but not by all varieties of this product. It should also be borne in mind that substituting one kind for another may lead to additional outlays by the consumer.

Both Portland cement and slag Portland cement are suitable for binding. But the latter kind is unsuitable for the production of a number of reinforced concrete parts. All kinds of energy fuel are interchangeable according to their calorific values, yet mazut is suitable for some consumers, a certain grade of coal for others, and both coal of different grades and mazut for still others. Besides, the preliminary treatment of coal -- used instead of mazut — may be required, depending on the type of furnace at a power station.

These examples, which may be multiplied, show that an optimum transportation plan must be drawn up with due regard for the interchangeability of products.

The problem of determining the minimum haulage effort and thereby the minimum transportation costs, with due regard for interchangeability, may be solved in the following manner.

Let us assume that there are suppliers A_1, A_2 and A_3 who produce the goods a_1, a_2, a_3 and a_4. Supplier A_1 produces all these products, A_2 the products a_1, a_2 and a_4, and A_3 the products a_1, a_2 and a_3. All these products are interchangeable within certain limits, the proportions in which one product is replaceable by another being known. Let us assume in our example that a unit of the product a_3 when replaced is equal to 0.5 of a unit of the product a_1, 1.5 units of the product a_2 and 2 units of the product a_4.

Let us assume further that there are four consumers: B_1, B_2, B_3 and B_4. Some of their requirements can be satisfied only by certain products allowing of no replacement. For example, consumer B_1 requires 3,600 units of the product a_1 and 1,020 units of the product a_3, and these requirements cannot be met by any other products. A portion of the demand of consumers B_1, B_2 and B_3 can be satisfied by various products. To describe these interchangeable requirements let us introduce the following notations: c_1 are requirements which can be met by the products a_2 and a_3, c_2 are the requirements which can be met by the products a_2, a_3, and a_4, and c_3 are the requirements which can be satisfied by all products, i.e., a_1, a_2, a_3 and a_4.

Let us also assume that consumer B_4 has certain difficulties in using the product a_4. B_4 must process it if he is to use it; the cost of this amounts to 10 units.

The above initial data are presented in Table 3 (see Table 3 shown on the following page).

The left-hand columns of the table show the suppliers and the output of each product in physical terms in its typical units of measurement. The subscript of the letter "a" shows the product and the superscript, the supplier. For example, the

Table 3

Suppliers	Products	Volume of production in physical units	Consumption and Demand													
			B_1							B_3			B_4			
			b_1^1	b_3^1	c_1^1	c_3^1	b_1^2	b_3^2	b_4^2	b_2^3	c_2^3	c_3^3	b_1^4	c_1^4	c_2^4	c_3^4
			3 600	1 020	1 460	850	8 000	600	1 025	2 534	1 300	620	1 900	1 700	850	1 080
A_1	a_1^1	5 600	2.5			2,5	1.5					2	4			4
	a_2^1	1 367			22.5	22.5				18	18	18		36	36	36
	a_3^1	1 450		10	10	10		6			8	8		16	16	16
	a_4^1	525				40			24		32	32			52	52
A_2	a_1^2	10 160	2.5			2.5	2					3	4.5			4.5
	a_2^2	2 313			22.5	22.5				27	27	27		40.5	40.5	40.5
	a_3^2	1 500				40			32		48	48			62	62
A_3	a_1^3	2 000	2			2	3.5					1.5	1.5			1.5
	a_2^3	800			18	18				13.5	13.5	13.5		13.5	13.5	13.5
	a_3^3	980		8	8	8		14			6	6		6	6	6

notation a_4^1 in the fourth row shows that this is the product a_4 produced by supplier A_1.

The top right-hand rows of the table show the consumers and their requirements. For each consumer we show the volume of non-interchangeable demand in physical units and interchangeable demand in conventional units (in the units of the product a_3 in our example). The non-interchangeable demand is designated by the letter "b" with a subscript denoting the volume of the product supplied to satisfy the given requirement for the product and a subscript to denote the consumer. For example, b_2^3 indicates the demand of B_3 for a_2.

The table lists aggregate costs of production and delivery to the point of consumption per unit of product (the costs are given free place of consumption). (4) Thus, the figure 2.5 at the intersection of the column b_1^1 and the row a_1^1 denotes the costs per unit of product a_1 incurred by supplier A_1 and the delivery of this product to consumer B_1. The columns showing interchangeable demand (columns c_1, c_2 and c_3) are treated in exactly the same manner.

On the basis of these data we draw up Table 4 which will be directly used in our calculations (see Table 4 shown on the following page). This table differs from the previous one in that non-interchangeable, and not merely interchangeable, demand is represented in it in conventional units of measurement. Correspondingly, the costs of production and delivery are also included per unit of conventional product.

Since the use of the product a_4 by consumer B_4 causes additional outlays, the latter are added to the costs of production and shipment. In the squares of the table corresponding to the delivery of the product a_4 to consumer B_4 (columns c_2^4 and c_3^4) the costs of additional processing of the given product (also per conventional unit) are added to the costs of production and delivery per conventional unit.

To eliminate impossible or undesirable deliveries, clearly excessive costs, assumed to equa 100 units in the present example, are indicated in the corresponding squares of the table. Such costs are shown, in particular, in the columns b_1 for all rows corresponding to the production of all other items, except for product a_1. For example, in all columns c_1 the costs equal to 100 are shown in the rows corresponding to the production of a_1 and a_4.

The following conditions necessary for the calculations hold for this table.

First, there must be a balance between total output and total requirements expressed in conventional units. Mathematically, this is expressed as shown in the illustration on the following page.

***

Table 4

Suppliers	Products	Volume of production in physical units	Volume of production in conventional units	Consumption and Demand														
				B_1				B_2			B_3			B_4				
				b_1^1	b_3^1	c_1^1	c'^1_3	b'^2_1	b_3^2	b_4^2	b_2^3	c_2^3	c_3^3	b_1^4	c_1^4	c_2^4	c_3^4
				1 800	1 020	1 460	850	4 000	600	2 050	3 800	1 300	620	950	1 700	850	1 080
A_1	a_1^1	5 600	2 800	5	100	100	5	3	100	100	100	100	4	8	100	100	8
	a_2^1	1 367	2 050	100	100	15	15	100	100	100	12	12	12	100	24	24	24
	a_3^1	1 450	1 450	100	10	10	10	100	6	100	100	8	8	100	16	16	16
	a_4^1	525	1 050	100	100	100	20	100	100	12	100	16	16	100	100	31	31
A_2	a_1^2	10 160	5 080	5	100	100	5	4	100	100	100	100	6	9	100	100	9
	a_2^2	2 313	3 470	100	100	15	15	100	100	100	18	18	18	100	27	27	27
	a_4^2	1 500	3 000	100	100	100	20	100	100	16	100	24	24	100	100	36	36
A_3	a_1^3	2 000	1 000	4	100	100	4	7	100	100	100	100	3	3	100	100	3
	a_2^3	800	1 200	100	100	12	12	100	100	100	9	9	9	100	9	9	9
	a_3^3	980	980	100	8	8	8	100	14	100	100	6	6	100	6	6	6

$$\sum^{j}_{ji} a_{i} = \sum^{k}_{kf} b_{f} + \sum^{n}_{mn} c_{m}$$

$i = 1 \ldots r,\ f = 1 \ldots p,\ m = 1 \ldots s,$
$j = 1 \ldots p,\ k = 1 \ldots s,\ n = 1 \ldots t,$

here r is the number of suppliers,
p is the number of products,
s is the number of consumers, and
t is the number of variants of interchangeability.

Second, the output of a product for which there a non-interchangeable demand should be equal to greater than this demand.

Using the above notations, this may be expressed the following inequality:

$$\sum_{j=1}^{r} a^{i} > \sum_{k=1}^{s} b^{k}_{f} .$$

With the table drawn up in this manner, the opti- um transportation scheme can be calculated by y of the linear programming methods used in lving transportation problems.

Experimental estimates have shown that the ap- ication of the above method for solving practical oblems is quite feasible. The calculation of ble 4 on a M-2 Electronic Computer through the solving components method lasted about three minutes (5), including the introduction of the initial data and the calculation program as well as the presentation of the results in a form convenient for use.

The result of the calculation is presented in Table 5 showing the optimum pattern of assigning suppliers to consumers as regards transportation costs. The filled-in squares show how much production a given supplier is to deliver to a given consumer (in the squares where two figures are given, the upper one shows the volume of demand or supply in physical units and the lower one shows the same in conventional units). (See Table 5 shown on the following page.)

A number of difficulties are still to be surmounted in proceeding to practical calculations. The calculations of optimum transportation plans with allowances for interchangeability call for drawing up very large tables. Thus, to calculate the transportation of cement over the country as a whole, with administrative economic districts taken as consumers, requires a table of approximately 500 columns and 400 lines. If not administrative economic districts but specific railroad stations and river ports are taken as points of consumption, the number of columns in the table will amount to several tens of thousands.

It is perfectly clear that the transportation pattern according to this table can be calculated only

Table 5

Suppliers	Products	Volume of production in physical units	Volume of production in conventional units	Consumers and Requirements														
				B1				B2			B3			B4				
				b_1^1	b_3^1	c_1^1	c_3^1	b_1^2	b_3^2	b_4^2	b_2^3	c_2^3	c_3^3	b_1^4	c_1^4	c_2^4	c_3^4
				3 600 1 800	1 020 1 020	— 1 460	— 850	8 000 4 000	600 600	1 025 2 050	2 534 3 800	— 1 300	— 620	1 900 950	— 1 700	— 850	— 1 080
A₁	a_1^1	5 600	2 800					$\frac{4\,360}{2\,180}$					$\frac{1\,240}{620}$				
	a_2^1	1 367	2 050								$\frac{1\,367}{2\,050}$						
	a_3^1	1 450	1 450		$\frac{850}{850}$				$\frac{600}{600}$								
	a_4^1	525	1 050									$\frac{385}{770}$				$\frac{140}{280}$	
A₂	a_1^2	10 160	5 080	$\frac{3\,600}{1\,800}$			$\frac{860}{430}$	$\frac{3\,640}{1\,820}$						$\frac{1\,900}{950}$			$\frac{160}{80}$
	a_2^2	2 313	3 470			$\frac{973}{1\,460}$					$\frac{1\,167}{1\,750}$				$\frac{173}{260}$		
	a_4^2	1 500	3 000				$\frac{210}{420}$			$\frac{1\,025}{2\,050}$		$\frac{265}{530}$					
A₃	a_1^3	2 000	1 000														$\frac{2\,000}{1\,000}$
	a_2^3	800	1 200												$\frac{800}{1\,200}$		
	a_3^3	980	980		$\frac{170}{170}$										$\frac{240}{240}$	$\frac{570}{570}$	

by electronic computers. Yet the machines now available do not have the so-called "operational memory" sufficient for this purpose. Nor have the long-term memory devices in them been adequately developed. Therefore in designing new electronic computers for economic estimates it is necessary to provide them with a more powerful operational memory and improve the long-term memory devices.

The proposed scheme of calculation does not solve the major problem of taking account of the varying effectiveness of using the same product by different consumers when demand is interchangeable. In this case the introduction of effectiveness factors violates the balance between the amount of production and that of demand. The solution of this problem is an urgent task.

Calculations involving interchangeable products require, of course, technical interchangeability coefficients. The indices describing the ratios of interchange of some products for others are available for fuel, cement and a number of other materials. Yet the differentiation of these indices depending on the effectiveness with which the products are used by various consumers and for different purposes is almost totally lacking. It is necessary to work out coefficients of interchangeability for many products, and particularly coefficients which will be differentiated according to the effectiveness of the products' use. Incidentally, they are needed not only for the calculations in question but also for other problems of planning and economic analysis.

If no account is taken of additional outlays involved in the use of a product, the result of the calculation does not depend on outlays on production. Consequently, in these cases calculations can be performed on the basis of transport costs alone. Yet in accounting for the additional outlay involved in the use of the product, the indices of production outlays become quite essential.

In economic estimates production costs are us ally used as indices of production outlays. In our opinion, in this case it is desirable to use an inde calculated according to the formula for the individual price of production, that is to say, an inde equal to the production costs for the given suppli plus the profit corresponding to the value of his capital used in production.

Another complex problem is that of determinin transportation costs. (6) In the system of freigh rates now current there are all sorts of preferen tial or penalty discounts and extras. The rates are set not in terms of a ton-kilometer of genera freight but are differentiated depending on the typ of the cargo and the distance of shipment so as tc stimulate the transportation of certain goods ove certain distances. Therefore, the direct use of e current rates for the calculation in question ould hardly be practicable.

Nor is the problem solved if the outlays on ansportation are calculated directly from the st of shipping, for they would take no account of e differences in outlays per ton-kilometer in ipping over different distances.

It is also quite essential that the cost of a ton- lometer differ from road to road, this difference ing explained chiefly by unequal volumes of haul- e over different roads. Since the difference in sts, depending on the road, is quite considerable times (for example, the costs for one ton- lometer over the Far Eastern Railway amounted 5.917 kopeks and over the Tomsk Railway to 258 kopeks, according to the report for 1958), the e of these indices as a criterion of the optimum ndition may essentially distort the results of the lculation.

Nor is the use of the index of distance as the iterion of the optimum desirable, one reason be- g that different kinds of transportation can be ed.

It appears that calculating optimum transporta- n plans will require the calculation of special lices describing the real outlays of social labor transportation.

Although a number of necessary indices are lack- at present, the possibility of taking account of erchangeability in the linear programming tech- que offers great promise in the planning of ship- nts.

But the effect of the calculations in question is confined to this. Since they can be performed h electronic computers within a very short time, periods required for drawing up supply and ipment plans and introducing the necessary cor- tions in the process of fulfillment of these plans be reduced considerably. (7) This is a sepa- e problem of considerable importance.

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n our opinion the significance of calculations formed with allowances for interchangeability nscends the determination of optimum schemes hipments. We may note in particular that ugh these calculations the prices free station of ival can be determined for all points of consump- of a product or interchangeable products.

ithout going into this special and quite compli- ed problem, we shall merely point to the follow- fact. If we take the prices free station of ival obtained as a result of calculating the opti- n transportation plan, and establish that the sup- rs must pay the state a rent also determined by ns of the calculation under discussion, the cal- ted prices will stimulate deliveries in accordance with the optimum plan to the maximum degree. Any deviation from the delivery plan will lead to a decline in the profits derived by the supplier. A further study of this question will evidently make it possible to draw up certain recommendations concerning the use of the calculations of optimum shipments in the practice of establishing prices free station of arrival.

Calculations according to the method considered above also make it possible to approach the problem of the most rational investment of resources in the development of the branches of the national economy from the viewpoint of ensuring minimum costs for certain products at the places of consumption. On the other hand, if production in any branch declines because the demand for the product decreases, the calculations under discussion will enable us to gauge the sequence in which the enterprises in question should be shifted to the production of other goods.

Footnotes

(1) *Metod razreshaiushchikh slagaemykh* — translator.

(2) A. Aleksandrov, A. Lur'e and Iu. Oleinik "Electronic Computers in Operational Planning," *Avtomobil'nyi Transport*, 1959, No. 6.

(3) A. L. Brudno, Doctor of Physical-Mathematical Sciences (Electronic Control Machine Institute of the USSR Academy of Sciences), has perfected the method suggested by A. L. Lur'e and evolved a rigorous mathematical proof of its applicability in a general case. Calculations under this method are quite simple. As distinct from the simplex and distribution methods, it is suitable for solving all transport problems, i.e., there are no cases of "degeneration," to use a mathematical phrase.

(4) In our opinion it is advisable to calculate the optimum plan of shipments not according to distances but according to transportation outlays. This is more suitable for the problem under discussion (see below).

(5) The calculations were performed at the Electronic Control Machine Institute of the USSR Academy of Sciences according to a program prepared under the guidance of A. L. Brudno, Doctor of Physical-Mathematical Sciences, by V. D. Belkin, A. F. Tretiakov and the present author.

(6) Of course, the requirement to ensure minimum transportation costs of products, even with allowances for their interchangeability, cannot be the sole criterion in drawing up transportation plans. Yet this criterion seems to us the most important one.

(7) It should be borne in mind that in principle

it is possible to mechanize the collection and preliminary processing of the initial information on the supply of materials and equipment. In particular, it has been noted in the press that it would be advisable to submit requests to supply organizations in the form of perforated cards ready for further entries.

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Voprosy Ekonomiki, No. 5, 196

A. KATS:

Concerning a Fallacious Concept of Economic Calculations

Last year L. V. Kantorovich, Corresponding Member of the Academy of Sciences of the USSR, published his book *Economic Calculation of the Best Use of Resources*, and No. 1 of the journal *Voprosy Ekonomiki* for 1960 carried his article on the same subject entitled "On the Calculation of Production Inputs." (1) As a mathematician L. V. Kantorovich deserves credit for formulating in the late '30s the main principles of a new branch of applied mathematics — linear programming — which has been increasingly used for solving complex economic problems. In his latest works, however, L. V. Kantorovich appears more as an economist than a mathematician and presents a general system of economic calculations.

It is quite obvious that even the best mathematical methods can be misapplied in a certain field of objective phenomena and lead to fallacious results. Of primary importance, therefore, is not only the degree of refinement of the mathematical means used, but also a correct interpretation of their real essence. L. V. Kantorovich's general concept, unfortunately, provides a classic example of the unjustified application of correct mathematical methods in a particular field. The use of this concept may result in major miscalculations, and this applies especially to the solution of dynamic problems of the national economy. In the present paper we shall deal with this aspect of the question alone.

The essence of the economic calculation technique proposed by L. V. Kantorovich consists in introducing corrections for the scarcity of particular elements of production in computing actual production costs. The mathematical methods of economic calculation suggested by L. V. Kantorovich can find a certain sphere of useful application — when various favorable or unfavorable conditions, abundant or scarce resources required for the production of certain items are fixed and cannot b changed within a certain period of time, and consequently what is required, given these conditions and resources, is the variant of the maximum production of the necessary assortment of products, i.e., the optimum variant of production.

But L. V. Kantorovich by no means confines himself to this task. For example, he also suggests the use of his methods of economic calculation for choosing the best measures to change the conditions and resources of production themselve for the purpose of securing the greatest possible volume of production. Yet when the problem is posed not only statically, but also dynamically, th whole matter changes. The very approach to the combination of two methods — the balance method and the labor consumption method (or the "cost" method as it is called) (2) — may be twofold: eithe the reckoning of the scarcity of certain resources in determining the dynamics of economic development, should be subordinated to the problem of achieving minimum costs for certain items or, o the other hand, minimum costs for a number of products should be sacrificed, for the sake of taking account of the scarcity of the resources in question. The fact is that the scarcity of various resources is constantly changing, the nature and size of the shifts in both directions depending precisely on which approach is used for solving the problems of economic planning. In L. V. Kantorovich's concept, minimum costs of products are invariably placed in the background in favor of an allegedly complete reckoning of the scarcity of certain resources. Yet if this approach is taken, the cumulative effect over a number of years, far from resulting in the "optimum" variant of the development of social production (i.e., a general minimum of expenditures for a given increment o ocial production for a given level of all expendi- ures), as it should according to L. V. Kantorovich, ill in fact bring about considerable losses. This an be seen by analyzing L. V. Kantorovich's xamples. Thus, in considering a case involving a hortage of power supply, the author writes: "Sup- ose that at all the enterprises of a city the o.c. 'objectively conditioned" — A. K.) estimate of lectric energy is equal to approximately 0.2. Cer- in measures at a power station (grading coal be- re feeding it to the furnace, for example) could nprove the operation of the boilers and result in ore energy with the same expenditure of fuel. Yet e expenditure of labor on this work is considera- e and an extra kwh. of electric energy will cost 4 kopeks (0.12 of a working hour at a rate of 2 ubles per hour). For the power station this new easure is not advantageous — production costs ill increase ... Yet from the state's point of view is measure, of course, is expedient since the ex- nditure of labor at the power station will be re- ouped almost twofold at those enterprises which ill receive the additional electric energy — if we oceed from an o.c. estimate of one kwh." (p. 83)

By "objectively conditioned estimates" L. V. ntorovich means the evaluations placed on the ork of producing a unit of output of each kind or of fferent kinds of output with allowances for the arcity of the various resources. Since electric ergy is in short supply, the "o.c. estimate" of ectric energy is high, and the introduction at the wer stations of backward techniques leading to increase in production costs and a decline in the oductivity of labor becomes "profitable" and conomic," according to L. V. Kantorovich's emises. This is allegedly justified by the fact t the gain for society obtained at the enterprises nsuming additional electric energy more than mpensates for the losses at the power station.

It can easily be seen that the "o.c. estimates" in present case would merely paste the lable of rofitability" on a measure obviously involving sses to society. If economic estimates are based prices corresponding to the actual outlays on oduction, the power stations will look for ways d means of increasing the generation of electric ergy and reducing actual outlays on production. on the other hand, we proceed from the "high . estimates," any primitive techniques causing rise in these "estimates" and entailing a lower el of the social productivity of labor will appear ofitable." For example, grading of coal before ding it to the furnace may be done by hand or chanically without considerable additional out- s.

Further on we read: "... Many measures increasing the expenditure of electric energy and obviously inexpedient, given the existing energy balance, reduce production costs according to calculations and seem profitable. On the other hand, other measures resulting in a saving of electric energy prove unprofitable according to calculations or lead to an insignificant decrease in production costs (for the share of electric energy in the production costs of most products is insignificant — on the order of one to two per cent)." (p. 84) Thus, according to L. V. Kantorovich, because of a tight balance in the use of electric energy our efforts should not be directed towards advancing the methods and expanding the production of electric energy so that technical progress may be accelerated to the utmost, the productivity of labor steeply raised and consequently the costs reduced on the basis of increasing the consumption of electric energy, at least in the leading branches. On the contrary, it is allegedly expedient to introduce the kinds of measures involving a relative decline in the consumption of electric energy which would "prove unprofitable according to calculations or lead to an insignificant decrease in production costs," i.e., cause either a decrease or a rather insignificant rise in the productivity of labor in certain branches of industry and the national economy in general. What is suggested is tantamount in fact to checking technical progress and the productivity of labor in the national economy for the sake of taking account of the "shortage" of electric energy. It is just the opposite of what we should do to "broaden" a "bottleneck" like the balance of electric energy consumption.

In considering the problem of using scarce materials L. V. Kantorovich arrives at similar conclusions. "Suppose, for example, that it is possible to start the production of material A out of local resources, the cost of the material being 8 rubles a kilogram. If we proceed from the current production cost of this material, the measure should be rejected since it would increase the cost by 100%. If, on the other hand, we proceed from the o.c. estimate this production will appear quite profitable and therefore desirable, and of course this conclusion will be correct." (p. 96)

The above examples show that the application of L. V. Kantorovich's proposals in these cases would place the socialist economy in a worse position compared even with its capitalist counterpart. For in capitalist society a rise in price as a result of an excess of demand over supply attracts capital into the production of the scarce material, while the prospect of competition makes the capitalist introduce new and better methods of production. No capitalist would introduce obsolete inefficient techniques even if he could derive a certain amount of profit due to a temporary, comparatively high price of the product. The inevitable decline of prices as the supply of this product increases will quickly oust the insufficiently effective investment from the market. Furthermore, to ensure the longest possible period for the competitive position of new investment, each group of capitalists will introduce all technical novelties available.

A high level of the so-called "objectively conditioned estimates" stemming from the shortage of certain materials is in fact nothing new. This is an exact replica, though elaborated mathematically, of a rise in prices given an excess of demand over supply on the capitalist market. Yet this replica, despite ingenious mathematical treatment, is still much worse than the poor capitalist original, for in the socialist economy it would merely encourage the unjustified diversion of social labor into low-efficiency production.

L. V. Kantorovich obtains similar results in those cases when the productivity of labor in his estimates largely depends on the natural conditions of production. Thus, he writes: "Suppose it is possible in the conditions of our example to increase the yield of wheat on better soil by two centners per hectare due to better cultivation of land with a 10% increase in the expenditure of labor. Is the introduction of the new method advisable? Calculations according to direct expenditures of labor yield a negative answer. Indeed, a 10% increase in the expenditure of labor increases the output by 2/30 = 6.7%, i.e., the productivity of labor decreases. The calculation should be performed according to estimates computed with allowances for rent ... An additional production of two centners of wheat is evaluated (in terms of labor) as 2 x 0.633 = 1.267 days. Comparison with the increase in labor expenditure (1 day) shows that the new method saves labor and its application is economically justified." (p. 120) If less productive additional expenditures of labor on better soil are nonetheless more productive than those on worse soil, the former, in L. V. Kantorovich's opinion, are always "economically justified" and provide an example of the "optimum" solution of the problem. Actually, this would mean only somewhat worse conditions in the use of the better soil, a somewhat lower productivity of labor on it, which, however, should be preferred to still less productive additional outlays of labor on worse soil.

Marx gave a detailed analysis of decreasing differential rents given a declining rate of the productivity of additional expenditures on better land. To solve the whole range of such problems it is necessary to take into account changes in the additional productivity of labor. On the other hand, the use in planning of the "o.c. estimates" replacing the reckoning of direct labor expenditures could only push into the background the major importance of taking account of actual production costs precisely on better land. It is common knowledge that the use on better land of less productive additional expenditures which are nonetheless more productive than those on worse land is not a genuine solution of the problem (3) and that efforts should constant be made to find such new methods of the additiona use of resources as would entail a rise and not a decline in the productivity of labor on better land.

As applied to the use of equipment the "o.c. estimates" are represented by L. V. Kantorovich in the form of the "hire estimate." (4) The magnitude of the latter is equal to the saving of labor du to an additional unit of equipment under the optimum plan (p. 108). The economic meaning of the "hire estimate" of equipment, just as any other "o.c. estimate," amounts to an increase in the price ("estimate") of the given type of equipment depending on the extent of its scarcity. "Let us assume," L. V. Kantorovich writes, "that by addin another machine operator to job No. 5 it is possib to raise the productivity of the machine by 10%. The estimate of the working day is 30 rubles. Will the new measure pay? Let us reckon production costs in the conventional way. Expenditures per day for job No. 5 were 500 x 0.3 = 150 rubles. No these expenditures amount to 150 + 30 = 180 rubles The productivity of the machine, raised by 10%, will amount to 550 units and consequently the production cost of a unit of output on job No. 5 will be equal to 180/550 = 0.33 rubles, as compared with 0.30 rubles, i.e., will increase. The productivity of the machine operators likewise declines. Thus the measure might seem inexpedient. Let us now make the calculation with allowances for the hire estimate of equipment. The former production co is now equal to 1.5 rubles. The expenditures per day of work ... will amount to 750 + 30 = 780 rubles. Since the productivity is equal to 550, the unit cost of work on job No. 5 is equal to 780/550 1.42 rubles. A decrease in the expenditure is thu obtained, i.e, the measure in question appears expedient under the given conditions. It should be noted, however, that this measure is seldom taken in actual practice. If there is such a machine in the given section the problem of how it could be used in other sections is not taken into account, and without such a reckoning this measure seems inexpedient and will hardly be taken." (pp. 103-104) Taking a similar example, L. V. Kantorovic expresses his idea in still more definite terms: "It should be noted that in reality measures like t

bove are taken in a number of cases even when a
ise in costs is involved. The motive is the im-
ortance of the product and the desirability of
aising its output. Yet in such cases it is believed
nat the measure ‘contradicts economics.’ Actu-
lly, if the measure is expedient, correct economic
alculations, with allowances for specific condi-
ions in terms of o.c. estimates, should show the
xpediency of the measure. The conventional cost
stimates are one-sided: they include only visible
xpenditures of labor without taking due account of
uch a major factor as improving the utilization of
quipment.” (pp. 149-150)

Yet the matter is just the other way around. It
s precisely the estimates made according to pro-
uction costs or rather according to actual ex-
enditures in production that can correctly identify
nose cases when the measure “contradicts eco-
omics.” Indeed, what does the situation mean
conomically when, proceeding “from the impor-
nce of the product and the desirability of increas-
g its output,” additional manpower is used entail-
g “an increase in production costs” or what
mounts to the same thing, a decline in the produc-
vity of labor? This means that there have been
sproportions in planning economic development.
dditional manpower has been channelled not into
e production of highly effective equipment for ex-
nding the output of “important products” through
e growth of the productivity of labor, but into the
eration of less effective equipment with a de-
ine in the productivity of labor.

In all the above examples the “allowances for the
nortage” of electric energy, various materials
nd certain kinds of equipment under the so-called
ptimum variants” based on the “o.c. estimates,”
legedly for the sake of the “maximum growth”
the total volume of production, ultimately do
e same thing — encourage the use of measures
volving a less productive use of additional man-
wer as “expedient.” But since labor is the
eator of all wealth, the only real economic mean-
g of the “shortage” of certain kinds of materials,
uipment, electric energy, etc., consists in the
ct that the available recourses of manpower at
e given level of the productivity of labor, or the
ailable level of the productivity of labor with the
ven resources of manpower prove to be insuffi-
ent to meet a certain pattern of the socialist
ciety’s needs.

Let us assume that manpower resources are
own and that the growth of the socialist society’s
npower equals the growth of population; in this
se the growth of production per capita depends
tirely on the productivity of labor. Under such
nditions the “allowances for scarcity” through the additional, less productive use of a certain amount of manpower in certain sections of the socialist economy can only mean an acuter “scarcity” in the national economy as a whole.

Let us assume further that the manpower resources increase through their transfer from agriculture to industry because the growth of the productivity of labor in agriculture exceeds the potentially limited growth of requirements for agricultural produce (chiefly foodstuffs), while industry, due to the growing diversification of output, involves a practically unlimited growth of requirements. In this case the less productive use of additional manpower would be the worst variant for eliminating the “scarcity,” for the same additional manpower could and should be used, with a far greater benefit to the development of all social production, to increase the production of highly efficient equipment, or to expand the work of modernizing existing equipment, or to perfect technological processes so as to increase ultimately the output of the materials and equipment in short supply in the most effective way.

Consequently, the dynamic variants based on the “o.c. estimates,” allowing for different kinds of shortages, seem mathematically “optimum” only as a result of the limitations of the author’s economic vision and the premises on which his calculations are based. This stems from the fact that such material elements of production as electric energy, various materials and various kinds of equipment are assumed to be in short supply within a narrow sphere of production (within an enterprise, a group of enterprises, a branch or a number of branches), while the total manpower is not assumed to be in short supply. Actually, the only real source of a shortage of materials and equipment is the shortage of manpower or an inadeuqate level of labor productivity relative to a certain pattern of the socialist society’s needs. Drawing up the optimum plan of economic development with allowances for the shortage of certain raw materials, equipment, energy, etc., means nothing more than the optimum distribution of manpower and the conditions of the productivity of its labor among the various sections of production intended to meet a certain pattern of needs. Now, the shortage of manpower can be eliminated most effectively by raising its productivity, which is expressed in a constant and universal reduction in the individual actual expenses of production, the individual total labor expended in production. It is only in this way that the maximum saving of labor is ultimately attained in the socialist society, with a maximum possible growth of the productivity of labor and the volume of social production under the given conditions. Therefore, the actual expenses of production should be the highest criterion in economic calculations.

The calculations of the optimum economic development are sound if they avoid the use of any part of manpower in a less productive manner than is possible. As the quality of planning economic development improves it becomes possible to channel additional manpower in advance to ensure the priority growth of the productivity of labor in those economic sectors in which shortages exist and thereby to raise the rate of economic development in every possible way. In every sector of the economy in which there are shortages, great or small, any additional less productive use of manpower should be rejected and this additional manpower should be used, above all, to ensure the maximum possible growth in the productivity of labor everywhere, including the sector in which the shortage exists. Should there occur an initial breakdown in raising the output of a scarce product as a result of earlier shortcomings in planning or other causes (since the creation of additional more effective equipment, its modernization or the perfection of technological processes and the organization of production may take some time), this, as a rule, should be faced with equanimity, for the optimum use of all manpower and the resulting maximum growth of the social volume of production can be attained if the manpower is employed at a rising level of productivity.

Now, an economic plan based on "o.c. estimates" at the very best could at the outset, say, during the first years, ensure a higher rate of economic development in the sector where the shortage prevails with a less productive use of a certaion section of a society's manpower, depending on the shortage of the resources in question. But after a number of years such economic plans providing for a number of measures involving a less productive use of a certain portion of manpower for each year, would lead to a lower increment of social production than the economic plans based on reckoning the actual expenses of production and providing for measures involving the maximum possible growth of the productivity of labor in each portion of manpower for each year. At the worst, the latter plans could result in a lesser increment of social production in the first and the second years as compared with the economic plans based on the "o.c. estimates." But in a few years these plans would ensure a more rapid development of social production than if the so-called "o.c. estimates" were used, for each year would bring the results of "broadening the bottle-necks" on the basis of an exclusively systematic, consecutive, maximum growth of the productivity of labor of certain portions of manpower.

Let us assume, for example, that the fund of capital investments which may be channelled into a certain branch ensures for ten years a 60% annual increase in the productivity of labor in this branch for 8% of the employees each year, under the assumption of a maximum reduction in actual expenses of production. If use were made of technically less advanced variants calling for smaller specific investments in fixed capital, it would be possible with the same sum of capital investments to ensure a 50% increase in the productivity of labor for 10% of the employees each year. For simplicity we shall assume that in the interim the productivity of labor at the enterprises where there is no renovation of equipment remains constant and that throughout the ten-year period under consideration there is no need for increasing the number of employees in the branch in question.

According to the first variant, each year the volume of production in the branch increases by 4.8% due to the fact that each year the productivity of labor of 8% of the employees increases by 60% (0.08 x 0.6 x 100 = 4.8%). After ten years the volume of production will have increased by 48%. According to the second variant, each year the volume of production is to increase by 4% (0.1 x 0.4 x 100), and hence by 40% after 10 years. It is quite obvious that variant 1 is more advantageous although every year a smaller part of aggregate living labor is equipped with new techniques than in case 2. A third variant is possible in which with the same sum of capital investment it would be possible to derive, let us say, a 55% annual increase in the productivity of labor of 9% of the employees. The annual increase in the volume of production will then amount to 4.95% (0.09 x 0.55 x 100) and the increase for the decade will be 49.5%, that is, larger than under the first variant. But in this case the first variant should be preferred if we bear in mind the increase in the volume of production not only in the first year but throughout the decade.

In the above example it was assumed, for the sake of simplifying the estimates, that the productivity of labor at the enterprises into which no capital investment is channelled in a given year remains constant. Actually, the productivity of labor grows almost constantly not only as a consequence of the renovation of equipment but also as a consequence of perfecting the operating techniques. This perfection, as a rule, calls for fairly small additional investments. It is quite obvious that the more advanced the equipment of an enterprise, the more potentialities are latent in this equipment for

radual improvement as compared with less ad-
anced equipment. Therefore, if we take the
ecade as a whole, the productivity of labor and the
olume of production due to higher potentialities
or gradual improvement arising as a result of the
pplication of the first, more advanced technical
ariant will be growing more rapidly than if the
ird technical variant was used.

Under this heading comes a more general and
uite important consideration. Of decisive impor-
nce in the development of technology is the factor
f continuity — in the sense that the higher the
rogress achieved in the field of production at a
iven stage, the greater the possibilities for a sub-
equent step forward and the greater this step will
e. In other words, it is on the practical experi-
nce acquired as a result of technical progress that
e qualitative properties of the nascent technology
rge depend. The application of advanced equip-
ent over a given period creates the broadest
asis for evolving advanced technical solutions in a
ubsequent period. This conclusion will become
l the more important if we bear in mind the de-
elopment of not only one but all branches of pro-
uction, as well as the interconnections in the ap-
ication of certain technologies in various branches
of production. Therefore, to ensure the highest pace of extensive technical progress as a principal factor in the maximum increase of social wealth, the optimum relations in the growth of the volumes of capital investments and the social product should, with rare exceptions, correspond precisely to evaluations based on minimum expenses of production.

L. V. Kantorovich solves the problem of effectiveness of capital investments in a different way. Here is what he writes: "In a certain branch of mining in a given economic area the extraction is done with the help of the simplest methods. The number of workers is 2,000. The annual output per worker is 1,000 tons of ore and the annual wage per worker — 10,000 rubles. The local price of one ton of ore is 20 rubles, i.e., the price of the annual output per worker is 20,000 rubles. To increase the output it is decided to mechanize production. The initial investments amount to 80 million rubles and later equipping should proceed out of the profit accruing in the branch. The number of employed in the branch remains constant. There are two kinds of machinery available to mechanize the output: A and B ..." (p. 210) The data on the latter are represented by L. V. Kantorovich in Table 1.

Table 1

Types of Machines and the Effectiveness of Their Application

Machines	Number of employed workers	Annual productivity (in thousand rubles)	Operating expenses exclusive of wages (in thousand rubles)	Depreciation time (years)	Value (in thousand rubles)	Output per worker (in thousand rubles)	Per 1,000 rubles of output (in rubles)		
							Operating expenses and wages	Depreciation	Production Costs
A	10	800	60	5	800	80	200	200	400
B	20	3,200	60	20	8,000	160	81	125	206

Objecting to the preference from the outset for
e technically more advanced machine B, L. V.
ntorovich writes: "Let us calculate the hire
timate and effectiveness of each machine. For
e machine A we obtain: 10 workers operating the
chine using the simplest techniques would
produce 10 x 20,000 = 20,000 rubles' worth of output. Thus, the value of the additional output produced as a result of the mechanization is: 800,000 - 200,000 = 600,000 rubles. The annual expenses are: 160,000 + 60,000 = 220,000 rubles (depreciation and operating costs, exclusive of wages). The

net saving (and hire estimate) as a result of the application of the machine A is: 600,000 - 220,000 = 380,000 rubles a year. The effectiveness of investment is 380,000:800,000 = 47%. For the machine B the additional output is: 3,200,000 - 400,000 = 2,800,000 rubles. The net saving (and hire estimate) is: 2,800,000 - 400,000 - 60,000 = 2,340,000. The effectiveness of investment is: 2,340,000: 8,000,000 = 29%. ... The result obtained shows that the correct solution in this case would be the introduction of the machine A at the outset of mechanization. The enterprise acquires 100 such machines; this mechanizes the work of one half of the employed, while 1,000 workers will continue extraction with the simplest implements ... Accumulation for the year (without taking account of depreciation expenses) will amount to: 1,000 x 20,000 + 100 x 800,000 - (2,000 x 10,000 + 100 x 60,000) = 74,000,000 rubles. This will make it possible to acquire 90 more machines of type A and equip 95% of the branch under consideration with them ... After this will begin the equipping of the branch with the more advanced machine B. It would have been incorrect to introduce machine B at the outset. We could then have acquired only ten such machines and 1,800 workers would have continued extraction with the simpler implements. Accumulation during the year would have amounted to: 1,800 x 20,000 + 10 x 3,200,000 - (2,000 x 10,000 + 10 x 60,000) = 47,400,000 rubles, i.e., the re-equipment of the branch would have proceeded much slower than in the first case. It is easy to see that the resulting total re-equipment of the branch with machinery would also proceed quicker if we began the introduction of new machinery with machines A than if we started with machines B." (pp. 211-212)

But it is, to say the least, difficult to see the soundness of this conclusion. The chief, one might say, the fatal shortcoming of calculations like those performed by L. V. Kantorovich, apart from any other considerations, consists in the fact that it is by no means a matter of indifference for the development of each branch and for the national economy as a whole whether the most effective technical means are introduced five years earlier or five years later. As stated above, technically advanced equipment contains far greater potentialities for new improvements than the less advanced types, and this source of the growth of productivity of labor and the volume of production is of considerable importance for the development of the national economy. Let us assume that after the period of the complete mastery of the machinery, let us say after the machines have been in operation for three years, annual output increases by 2% a year on Machine A in the above model of L. V. Kantorovich, and by 4% a year on the more advanced machine B as a result of gradual improvements. Let us consider how these capital investments will function for ten years without taking account of the given factor, as well as by taking i into account (see Table 2 shown on the following page).

Without taking account of the gradual improvement of machinery, L. V. Kantorovich's solution o the problem of effective long-term investments o the basis of the "hire estimates" of equipment seems to be more favorable: if the branch is equipped first with machines A and then with machines B the total sum of accumulations (includin depreciation expenses) in ten years will amount t 1,119,300,000 rubles as against 1,108,000,000 rubles if the branch is equipped with machines B from the outset (the difference being 1.2%), while the gross output will amount to 2,246,000,000 rubles as against 2,063,800,000 rubles (the differen being 8.7%). If we take into account the gradual improvement of equipment the situation is entirel different: if the branch is equipped from the outs with the more advanced machines B the gross output will increase at a somewhat slower rate only in the first four years, than if the less perfect machines A were introduced at the outset. In ten years the cumulative sum of accumulations in the first case will amount to 1,594,700,000 rubles as against 1,222,700,000 rubles in the second case, i.e., 30.4% more, while the gross output — 2,504,600,000 rubles as against 2,349,400,000 rubles, i.e., 6.6% more. In the tenth year the exces of production will reach 18%.

But the advantages of introducing the more perfect machines B from the outset will be far greater. The process of mastering them from the outset will contribute to the accumulation of the experience necessary for creating, say five year later, still better machinery of the type B and to subsequent introduction in the branch under disc sion. As a result, the growth of production and accumulation over the ten year period will be mu greater. In addition, the growth of production an its higher technical level will have a favorable e fect on other branches. If, on the other hand, we begin with the introduction of machines A and pa over to machines B only five years later, the mo advanced type of machines B will, other things b ing equal, appear only ten years later.

It should be noted that in the above example of calculating the effectiveness of capital investmen L. V. Kantorovich proceeds from the fact that ca tal investments per unit of output for the more advanced machine B are much higher than for

Table 2

Estimates of Effectiveness of Capital Investments
(in million rubles)

	Equipping the Branch with Machines								
	First A and then B					B			
	Number of machines		Accumulation				Accumulation		
Years	A	B	Annual	Sum Total	Gross output	Number of machines	Annual	Sum total	Gross output
	Without allowances for gradual improvements								
1st	100	—	74.0	2.0	100	10	47.4	-0.6	68.0
2nd	190	—	122.6	124.6	154	16	63.8	63.2	84.8
3rd	200	—	128.0	244.6	160	24	85.8	85.0	107.2
4th	200	—	128.0	372.6	160	34	113.6	118.2	135.2
5th	200	—	128.0	500.6	160	49	154.3	152.4	177.2
6th	100	50	211.0	311.6	240	68	206.3	206.7	230.4
7th	10	95	285.7	237.3	312	94	275.3	274.0	301.0
8th	—	100	294.0	531.3	320	100	294.0	520.0	320.0
9th	—	100	294.0	825.3	320	100	294.0	814.0	320.0
10th	—	100	294.0	1,119.3	320	100	294.0	1,108.0	320.0
Total	—	100	—	1,119.3	2,246	100	—	1,108.0	2,063.8
	With allowances for gradual improvements								
1st	100	—	74.0	2.0	100.0	10	47.4	-0.6	68.0
2nd	190	—	122.6	124.6	154.0	16	63.8	63.2	84.8
3rd	200	—	131.2	247.8	163.2	24	88.9	88.1	110.3
4th	200	—	134.4	382.2	166.4	35	124.9	125.0	145.0
5th	200	—	137.6	519.8	169.6	51	179.3	176.3	202.4
6th	100	50	217.4	337.2	246.4	73	256.7	257.0	281.1
7th	10	95	286.5	263.7	312.8	100	358.0	398.7	384.0
8th	—	100	307.0	570.7	333.0	100	371.0	769.7	397.0
9th	—	100	320.0	890.7	346.0	100	384.0	1,153.7	410.0
0th	—	100	332.0	1,222.7	358.0	100	396.0	1,594.7	422.0
otal	—	100	—	1,222.7	2,349.4	100	—	1,594.7	2,504.6

hine A: 4 rubles compared to 1 ruble per ru- of output. Such cases are rare and far between adays. As a rule, the more that technical equip- t develops the greater are the absolute de- ases in investment per unit of output. All the e reason to say that there are no grounds for introducing the most advanced technical vari- right from the start.

way of “generalizing” the estimates of effec- ness of long-term investments on the basis of “hire estimates” of equipment, L. V. Kantorovich derives the plan-conditioned normal effectiveness for the national economy as a whole. (p. 198) If the entire meaning of the estimates of effectiveness of capital investment on the basis of the “hire estimate” of equipment within the framework of a certain branch is reduced to a delay in the introduction of more advanced equipment and thereby to a decline in the pace of technical progress, then the establishment of a uniform “normal effectiveness” for all branches of the national economy will result in new technical equipment being introduced, above all, in those branches where the share of expenditures of living labor in production expenses is greatest. In such branches a saving of living labor which is, as a rule, a predominant part of the total economy stemming from the introduction of new equipment will amount to the largest quantity with respect to the size of investment, and the indices of the effectiveness of capital investments calculated by L. V. Kantorovich will prove to be the highest ones. Yet these indices will primarily reflect only certain differences in the ratios of materialized to living labor among branches, but by no means the real effectiveness of capital investments in the development of the national economy. Furthermore, actually profitable capita investments may appear as inexpedient according to these estimates.

Let us assume that in two branches (I and II) th investments, actual expenses of production and gross output before and after the replacement of equipment are as follows (the annual wages per worker are assumed to be equal to 10,000 rubles, the ratio of the product for society to wages is taken as 1:1, and the expenditures of raw materials per unit of output remain unchanged when the equipment is replaced):

	Before the replacement of equipment		After the replacement of equipment	
	Branches			
	I	II	I	II
Fixed capital (in million rubles)	400	400	500	500
Period of amortization (years)	10	10	10	10
Annual depreciation (in million rubles)	40	40	50	50
Expenses on raw materials, fuel, and supplies (in million rubles)	400	300	520	360
Number of workers (thousands)	20	30	21	30
Annual wages (in million rubles)	200	300	210	300
Product for society (in million rubles)	200	300	210	300
Actual expenses on production (in million rubles)	840	940	990	1,010
Number of products (in thousands)	1,000	2,000	1,300	2,400
Price of a unit of production (in rubles)	840	465	840	465
Gross output in constant prices (in million rubles)	840	940	1,092	1,128

The following results are obtained if the effectiveness of capital investment is calculated by L. V. Kantorovich's method. In branch I, characterized by a higher organic composition of invested resources, the saving from the replacement of fixed capital will amount to 102 million rubles (1,092-990), or 20.4% of the sum invested in fixed capital (102:500). In branch II, characterized by a lower organic composition of invested resources, the saving will be equal to 23.6% (1,128-1,010 = 118:500). If we proceed from a "normal effectiveness" of capital investment assumed to be equal to 23%, the variant of the replacement of fixed capital in branch I will appear inexpedient, while that in branch II expedient.

Actually, the technical variant of plant replacem in branch I is more advantageous for the develop ment of the national economy than the technical variant in branch II. The additional investments the fixed capital of all branches being equal (100 million rubles), the annual productivity of labor worker in branch I will increase from 42,000 ru bles (840,000,000 rubles:20,000 workers) to 52,0 rubles (1,092,000,000 rubles:21,000 workers), i. by 24%, while in branch II — from 31,300 rubles (940,000,000 rubles:30,000 workers) to 37,600 ru bles (1,128,000,000 rubles:30,000 workers), i.e. by only 21%. The increase in gross output in branch I will come to 30%, while in branch II to ly 20%. An annual increase of 252,000,000 rubles the gross output of branch I and of 188,000,000 ibles in branch II will correspond to 100,000,000 ibles of additional investments in fixed capital. he seeming advantage of investment in branch II ccording to L. V. Kantorovich's calculation tech- que) stems from the organic composition of in- estment in this branch increasing comparatively ore rapidly.

The very concept of a uniform “normal effective- ess” of investment for all branches of the national conomy is theoretically untenable, for the result such estimates reflects, above all, differences in e technical and organic compositions of the in- ested resources. The application of the criterion “normal effectiveness” of investment to all anches would encourage investment in the bran- es characterized for one reason or another by a gher share of expenditures of living labor and ight lead to a declining rate of growth of the pro- ctivity of labor and the total volume of social pro- ction. We are leaving out the fact that in deter- ining priority investment in certain branches of e national economy account should also be taken the importance of the branches in question and any other considerations far removed from the echanical application of a uniform “normal rate of ectiveness” of capital investments for the entire tional economy.

The following conclusion suggests itself. One of e basic methodological errors of L. V. Kantoro- ch is that he proceeds from the concept of a single ptimum plan” in deciding both static and dynamic onomic problems, in other words, he mechani- lly extends the concept of “optimum variant,” itable for solving certain static economic prob- ms, to the solution of general dynamic problems. en the conditions of production are fixed and do change over a certain period of time, allowances “scarcity” can lead to drawing up a certain opti- m variant of total expenses which differ to a cer- n extent from the minimum expenses for each oduct. But when we deal with the preparation of ynamic program with changes in the very condi- ns of production and the kinds and degrees of arcity,” the optimum variant, with rare excep- ns, coincides with the variant which consecutive- ensures minimum expenses for individual kinds parts of the social product, for in the last anal- s this ensures the quickest rate of technical gress and hence the quickest rate of growth in productivity of labor and social production.

The essential methodological error of L. V. ntorovich in presenting the techniques of general nomic calculation is by no means negated by his gestion to conduct “optimum long-range planning” on the basis of a “dynamic system of estimates” and dynamic values of “normal effectiveness.” L. V. Kantorovich himself is forced to recognize the precariousness of constructing a “dynamic system of estimates.” Here is what he writes: “In drawing up a long-range plan, technical progress within the period in question should be taken into account and reckoned with along with existing technical methods. On the whole, taking account of the progress of technology must be based on definite forecasts of technical developments. In some cases, taking account of technical progress may be based on the contemplated introduction of a certain new technology, while in others, improvements within certain limits of existing technologies (higher productivity, lower unit costs, etc.) have to be tentatively planned on the basis of the experience accumulated in this branch. These data, of course, will not be at all exact and some may prove to be partially unjustified. It should be said, however, that this is not so essential, since this may effect merely the estimates for future years and the changes in these estimates do not have a great effect on the solution for the first years.” (p. 236)

True, according to L. V. Kantorovich, there is still a possibility of constructing a “normal system of estimates” ... “abstractedly, without making allowances for the requirements of the composition of output, without considering the data on the initial resources in productive capacities, etc.” Yet the “normal estimates can be used” only as “rough approximations to the dynamic system. It is evidently possible to use normal estimates for calculating the effectiveness of investment for subsequent years when any degree of accuracy in deriving the dynamics of estimates is hardly feasible, as we have already indicated. As for the expenses and output of the immediately following period, it would be more correct to use the o.c. estimates for the given moment (the current plan period) for approximate comparability.” (p. 237)

The trouble is not only that “any degree of accuracy in deriving the dynamics of estimates is hardly feasible,” and that hence it is possible in practice to use only the “o.c. estimates” for the initial period. The real trouble is that the use for the immediately following period of the “o.c. estimates” for the initial period and the “normal effectiveness” related to them would impose an ultimately slower rate of technical progress and growth of social production over the long-range planning period, i.e., would predetermine worsening of the real content of the “dynamic system of estimates,” even if it were possible to calculate it in advance. A departure for some reason or other from the minimum actual expenses of production in new capital investments is permissible only by way of exception and if the premises of subsequent technical progress are not impaired thereby.

In L. V. Kantorovich's opinion, as a matter of principle wholesale prices "should approximate the o.c. estimates." Moreover, the wholesale prices "should reflect the hire cost" of equipment as well as "those deviations stemming from a temporary shortage of the particular kind of equipment, or its available reserves, sharp increases in the demand for this kind of product, etc." (p. 155) This kind of wholesale price setting would make the results of economic calculations much worse. In this case wholesale prices would not merely "fix" the use of less productive techniques but would eliminate the possibility of estimating that very "shortage" which is reflected in the "o.c. estimates." This would stem from the gap between wholesale prices and actual expenses of production as well as from repeated superimpositions of some prices on others. Consequently, the social accounting of actual expenses of production in the consecutive phases of production would be destroyed to all intents and purposes and the "o.c. estimates" would hang in mid-air, although their entire meaning lies precisely in their being different from the actual expenses of production for individual products.

It can be easily seen that at the bottom of all the above-listed errors is the fact that L. V. Kantorovich ignores the Marxist theory of the expenditure of labor as the substance of social costs of production. This leads, in particular, to the totally unsound nature of his suggestions in the field of price formation.

From this erroneous approach in applying higher mathematics for purposes of general economic calculations it does not follow that higher mathematics cannot be widely applied in the general economic calculations of planning. This conclusion would be absurd. On the contrary, a vast field for the application of mathematics in economics is opening up in connection with electronic computing techniques. This refers, above all, to the accurate calculation of actual costs of production, against which L. V. Kantorovich rails for no reason at all; these estimates underlying any correct economic calculation cannot be performed without applying higher mathematics and electronic computing techniques.

Footnotes

(1) Translated in Problems of Economics, May 1960 — editor.

(2) See L. V. Kantorovich, Ekonomicheskii raschet nailuchshego ispol'zovaniia resursov, USSR Academy of Sciences Publishing House, 1959 p. 169. In the following the pages of this book are indicated in the text.

(3) L. V. Kantorovich arrives at the opposite conclusion and no other: "In evaluating the new method of production ... we have found that more intense treatment of soil is advisable for increasing the yield. If, on the other hand, we judge by th visible expenditures of labor, a 30% increase in them results in merely a 20% rise of output. The expenditures per unit of production increases, the productivity of labor declines, and the application of the new method therefore seem inexpedient. Thus, calculations according to direct expenditure of labor can be misleading (! — A. K.) in solving the problem of the correct use of the factors of production." (Voprosy Ekonomiki 1960, No. 1, p. 133.)

(4) In his book the author writes: "We use the term 'hire estimate' since this is an estimate of the pay which would be justified if the machine in question were hired for a certain period. This estimate may also be regarded as rent for equipment, the possible magnitude of which can be calculated though we do not pay it." (p. 102)

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ORGANIZATION OF STATISTICS AND ACCOUNTING

Vestnik Statistiki, No. 8, 1960

. N. STAROVSKII:

)n Mechanization of the Labor of Engineering nd Managerial Personnel*

The Soviet people are successfully implementing e fundamental task set by the 21st Congress of the PSU, namely, in as short a time as possible to reate the material and technical base of commu- sm, to ensure the further consolidation of the eco- mic and military potential of the USSR and at the me time to satisfy ever more fully the growing aterial and spiritual requirements of the people.

Measures have been taken in our country to pro- ote further technical progress, to widely intro- ce in the national economy modern techniques of gh velocities, pressure, tensions, and to develop tomatic lines, shops and automatic plants. This ll in large measure ensure the fulfillment and erfulfillment of the Seven-Year Plan assignments r national economic development and also the suc- ssful solution of the historic task of overtaking d outstripping the more developed capitalist coun- es in per capita production and of creating the ghest living standards in the world.

Today, when the productive forces are steadily veloping, when socialist production is steadily in- easing and technical progress moving forward at accelerated rate, the significance of the labor of gineering-technical personnel, construction en- eers and designers, the personnel of scientific titutions and managerial staffs is growing more d more. We remember what Comrade N. S. rushchev said at the Plenary Meeting of the Cen- l Committee of the CPSU on the changing and er-growing role of engineering-technical person- and construction engineers in the national econ- y. In a speech at the Plenum he said:

"We must not automatically declare all people o work behind desks office-drudges and bureau- ts. If we only bear in mind the creative effort required to improve machinery and perfect production we shall clearly see that the people thus employed play a very important role in developing production. To create an automatic line, for example, designers and other specialists have to work in their study rooms and make the necessary computations, design the new machines, develop new principles of technology in introducing automation.

"And if one were to carefully analyze who had developed the new automatic line he would realize how great was the part played by the specialists... The people who work in study rooms are by no means bureaucrats. They are creative workers who produce new things, whose knowledge is most up-to-date, who skilfully apply it in production and promote technical progress."

"Under communism," continued Nikita Khrushchev, "there will be far more scientific institutions, designers and other specialists; possessing great knowledge the workers will also operate intricate highly productive machinery. It is important that we also prepare for this psychologically; we must guide and organize the work precisely in this direction" (Plenum of the Central Committee of the CPSU, June 24-29, 1959, verbatim report, p. 457).

This increases ever more the importance of promoting technical progress, of mechanizing and automating engineering and managerial work. In connection with the transition to the seven-hour working day and the prospects of further reducing it we must work to increase the volume of engineering and designing work by raising labor productivity in the respective specialties. Extensive mechanization and automation of accounting, designing and engineering jobs will ensure, in addition to greater labor productivity, a saving of time and a speedier solution of scientific and engineering problems.

Mechanization and automation will increase the accuracy of computations and calculations. Computors have already helped and will continue to

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ummary of a report delivered by the head of the SR Central Statistical Administration at a confer- e on mechanization of the labor of engineering managerial personnel held in June 1960.

help solve complicated technical and technical-economic problems which previously could not be tackled because of the immense calculations involved. Technical decisions and planning will be much sounder from both the scientific and engineering standpoint. When mechanization is introduced management of production will become far more effective. Enterprises will be able to master the output of new commodities much more quickly. Control over the execution of assignments will improve and continuity will be assured in supervision of production.

Mechanization and automation of managerial work will reduce the cost of the managerial process and make it more effective. It will ease the work of the managerial staffs, improve it qualitatively and in the final analysis help to raise the material and cultural level of the working people.

Extensive mechanization and better organization of the labor of millions of engineers, technicians, designers, planners, calculators, accounting and managerial staffs (these problems concern millions of people) will release several hundred thousand of them for jobs in production or in research and engineering. But the basic aim of mechanization is to make work easier for millions of people, to save time spent on computations and calculations and create the conditions which would make their work more productive and creative.

Even in the early years of socialist construction V. I. Lenin devoted serious attention to the proper organization and to raising the productivity of managerial personnel and to providing them with equipment. In his article "Better Fewer, But Better" Lenin wrote: "Announce at once a competition for compiling two or more textbooks on the organization of labor in general, and of the work of administration in particular." (1) Lenin offered to "send several trained and conscientious persons to Germany, or to England, to collect literature and to study this question." (2) In a decision on the work of the Vice-Chairmen of the Council of People's Commissars and the Council of Labor and Defense V. I. Lenin wrote: "... the Vice-Chairman must see to it that the best and latest books on labor organization and management, especially American and German publications, are translated and published." (3) V. I. Lenin suggested that instructions and directives issued orally should be taken down in shorthand and that dictaphones be used.

In later years, too, the Party and government gave much attention to the rational organization of supervision and to mechanizing the managerial apparatus. The 15th Party Congress called for mechanization of clerical work and accounting, and the 16th Party Conference adopted a decision to ensure "the spread in the next few years of the mechanization of accounting in all the larger economic institutions."

Of great importance for the development of mechanization of accounting was the extensive program adopted in April 1949 for increasing the domestic output of calculating machines and increasing the provision of these machines to people employed in accounting and calculating operations In December 1955 an important decision was take to ensure supplies of equipment, gauges, instruments and materials for planning organizations.

The reorganization of the management of industry and construction carried out in 1957 on the initiative of Comrade N. S. Khrushchev played an important part in the development of mechanizatio of accounting. In his report to the 7th Session of the USSR Supreme Soviet N. S. Khrushchev said: "The measures taken to improve management in i dustry and construction make possible the extens centralization of accounting and statistics, a radical curtailment and simplification of accounting an reporting, and the extensive mechanization of accounting by establishing calculating machine stations under the Central Statistical Administration agencies."

In its directives on the target figures for the development of the national economy in 1959-1965 the 21st Congress of the CPSU decided that the structure of the administrative apparatus in the center and in the localities must be simplified so as to make it more effective, qualified and economical, to bring leadership closer to production and to raise its level.

Following the implementation of the measures the Party and government certain improvements have been achieved in the mechanization of managerial work. This refers particularly to mechanization of accounting and calculating work: the domestic manufacture of calculating machines ha been developed, a calculating machine network o ganized and personnel trained for this purpose. Between 1946 and 1960 the number of calculating machines in the Soviet Union has increased 8.5 times, the number of computing stations and mec anized accounting factories has risen 6 times an the number of calculating machine bureaus 18 times. From 1950 to 1959 the network of the US Central Statistical Administration alone trained more than 20,000 operators, mechanics, organiz and planners of mechanized accounting. Howeve all this is most inadequate compared to the requirements of our rapidly developing economy.

The extensive program elaborated on N. S. Khrushchev's initiative and approved by the gove ment in December 1959, a program which solves

principal technical, organizational and metho-
logical questions in this field, is a new phase in
development of mechanization of accounting,
signing and engineering work.

In the earlier stages of the country's development
ention was naturally focussed on more important
more urgent problems. Therefore, the level of
chanization of managerial and engineering labor
far behind the national economic requirements
the level of automation and mechanization of
duction processes.

In accordance with government directives a
ries of measures will be taken in the next few
ars to ensure the extensive application of modern
lculating techniques, means of obtaining, sum-
rizing and transmitting information, drafting and
plicating techniques, means of mechanizing book-
eping and storing documents at enterprises,
ices and organizations. These measures will in-
ve the mechanization and automation of engineer-
, accounting, statistical, administrative and
nagerial jobs.

t is essential in the very near future to consid-
bly increase the capacities of plants which pro-
e the machines, equipment, appliances, supplies,
truments and materials required for all this.
implementation of this responsible task must
assured by the work of many economic councils,
luding the Moscow city, the Moscow Region, the
ingrad, Sverdlovsk, Kiev, Kharkov, Lithuanian,
ov, Penza, Riazan and Kursk Economic Councils.

he government has adopted a concrete program
extensively developing scientific research and
igning work connected with the manufacture and
lication of modern technical means for mechan-
g the work of engineering and managerial staffs.
State Committee of the USSR Council of Minis-
on Radio Electronics, with its Scientific Re-
rch Calculating Machine Institute, and the State
mittee of the USSR Council of Ministers on
omation and Machine-Building are extending
r research and designing work in fields con-
ed with the development and application of equip-
t to mechanize and automate accounting and cal-
ting work. Special bureaus for the serial
duction of new designs have been established at
calculating machinery plants. The State Com-
ee on Construction of the USSR is undertaking
arch and experimental work on the organization
mechanization of designing and prospecting, en-
ering, drafting and duplicating work.

e economic councils, ministries, departments,
ntific research and planning organizations as
as plants are working on new designs, on the
truction and effective use of existing technical
ns of mechanization and automation of managerial work, on drawing up suggestions for applying control machinery and systems for automating production processes and mechanizing engineering and managerial work in various branches of the national economy.

In the next few years mechanization and automation of engineering and managerial work will be widely developed by training considerably more personnel for this purpose in the higher educational institutions and specialized secondary schools. The Ministry of Higher and Specialized Secondary Education is adopting a number of measures towards this end. The Central Statistical Administration is increasing the network of courses as well as the enrollment for training personnel of mass trades for calculating machinery installations.

The governments of the Union Republics have approved decisions ensuring the realization of the directives of the USSR Council of Ministers for the further development of mechanization of accounting, designing and engineering work, and in a number of instances have provided for certain additional measures. Thus, the Council of Ministers of the Kazakh Republic has instructed the economic councils to make the necessary preparations for a transition of the calculating machine stations and bureaus of enterprises to a cost accounting system, to start production of special materials for calculating machine installations at furniture-making factories, etc.

Many economic councils, such as the Leningrad, the Moscow Region, the Kuibyshev, the Perm and other Councils have taken measures to increase the efficiency of the available computing machinery, reorganizing the existing calculating machine stations into larger units, establishing two shifts at these stations and working out a program for mechanizing other sections of accounting. The Smolensk Economic Council is organizing the duplication of technical data by using automatic printing machinery and microfilming.

A number of executive committees (such as the Stalingrad, Kharkov, Lvov Region, Moscow and others) are working on the further development of mechanization of accounting, engineering, designing and computing operations at the enterprises and organizations under their jurisdiction.

Some industrial enterprises are beginning to use the newest techniques of controlling production. Thus, the Magnitogorsk Iron and Steel Works is applying (so far experimentally) phototelegraphy for transmitting data of the analysis of smelting, and industrial television for remote control of technological processes.

A calculating center has been established under the USSR State Planning Committee which, with the help of modern techniques, will make it possible to solve problems connected with the elaboration of current and long-range plans, with determining optimum directions in planning and managing the national economy as well as with other state planning problems.

Recently the USSR Academy of Sciences held a scientific conference on the uses of mathematics in economic research and planning which was attended by many mathematicians, economists, planners and statisticians. Proper application of mathematics and modern calculating techniques will improve the present methods of economic calculations and help to improve planning and statistics. Problems in the field of economic calculations, planning and statistics which were quite impossible to tackle with the old techniques can now be solved successfully.

The important thing today is to increase the output of computing equipment and to apply it on a greater scale. Calculating machinery is the basis for mechanizing and automating engineering and mangerial work. The output and assortment of accounting and calculating machines in this country will grow appreciably in the coming years. Most important is the organization of serial production of the highly efficient electronic computors suitable for the mechanization of accounting, statistical, planning and calculating work.

Electronic computors can be effectively employed in accounting and statistics, for example, in processing census returns, in working out balancing accounts — including inter-branch balances, etc. — in a number of economic planning calculations, as for example, the drawing up and analysis of interbranch relations, the drawing up of balances showing proportions between interconnected branches of production, in calculating the effectiveness of capital investments and also in many other operations. Electronic machinery is also destined to play a big role in primary accounting. Thus, the use for a number of years of the electronic computer EV-80-3 at the Rostsel'mash plant has reduced calculating work in drawing up the pay-roll and in stock taking by 10 to 15 times.

It would be a mistake, of course, to think that electronic computors can completely replace ordinary calculating machines. The experience of other countries shows that electronic machines do not eliminate the need for the extensive use of keyboard and punching machines, particularly since these models will also operate in the future on electronic elements.

It is vitally important to ensure the full and rational utilization of calculating machines already available at the installations of enterprises and organizations, as well as the mass of highly productive calculating equipment which the natio al economy will produce during the current seve year period. Experience shows that the calculat equipment available in the national economy toda is not being utilized adequately. About 8% of the available computing machines are idle for variou reasons. Many machines are in operation for on a few hours a day.

The new computing equipment should cause a revolution in accounting itself. Of great importance for ensuring uniformity in methods of accounting, in forms and schedules for handling bu ness documents and verifying their accuracy and proper utilization is the decision that the calculating machine stations of enterprises and constr tion sites in planning their work and in regard to methodology will be subordinate to two bodies — the management of the enterprise (construction site) and the respective Central Statistical Admi istration agencies. This dual subordination of ca culating machine stations is of great importance both for tackling current problems and also with respect to the prospects of developing the mecha ization of accounting under the conditions of buil ing a communist society.

The prospects of improving the system of accounting and of developing state statistics depen on the development of a uniform system of calcu lating machine stations. The dual subordination the machine calculating stations is an important step in this direction. The new technique will doubtlessly help to solve a number of important problems which today we are tackling experime tally. We already possess experimental data wh make it possible to link the regional station with central station, or an enterprise with the region station, with the help of up-to-date means of con munication and without the aid of man. The calc lating machine station of an enterprise, summar izing the data on its activity, will be able autom cally to transmit the results to the calculating machine station of the region and the republic. this way the problem of accuracy will be fully solved and a new rise in labor productivity ensured. This is not phantasy but experimental w features which we already see and perceive in t organization of accounting and statistics in the communist society. Accounting and statistics in the communist society will doubtlessly be based a system of calculating machine stations equipp with highly productive computing machines and linked together from top to bottom by the most to-date means of communication.

A very important problem is that of mechaniz and automating planning and designing jobs. At present hundreds of thousands of skilled person

e thus employed. Furthermore, the volume of
anning work will, of course, grow from year to
ar and with the present level of technology this
uld require a tremendous increase in the number
planners, designers, calculators, etc. Full scale
tomation and mechanization of planning and de-
gning work will assure such an increase in labor
oductivity that the new big assignments will be
complished by the personnel now available. If
e staffs will have to be increased, it will be done
a far smaller scale.

At the present time mechanization of planning and
signing jobs is all but absent. At times the plan-
ng, designing and technological bureaus and insti-
es lack even modern drawing instruments, the
cessary furnishings and even many simple de-
ces and paraphernalia facilitating and accelerating
signing and planning work. Lack of special pen-
s and paper prevent the application of the repro-
ction methods commonly used abroad. Calcula-
ns show that if these methods were applied in the
oduction of only 50% of the designs, 20,000 to
,000 copyists would be released and up to 200
llion rubles saved annually in wages alone. One
the institutes of the State Committee on Con-
uction, for example, spends up to two days on
reproduction and verification of a drawing while
y five to ten minutes are needed for obtaining a
lex copy.

A serious shortcoming in the work of the design-
and technological organizations is lack of a uni-
m over-all system of drafting work, branch
ndards and norms, and a developed system of
hnical information.

The technique of reproducing technical drawings
also very backward. We must improve the qual-
of our photo-print apparatus. Microfilming —
ighly productive means of duplicating documents
other materials — is hardly applied at all.

Microfilming, as illustrated, for example, in
ulating the census returns is not only extremely
ful for planners but also in other areas of work.
s, the district census returns would have re-
red 2,000 volumes of tables, each weighing 2.5
Each of them would have had to be reproduced
everal copies for the districts and regions.
vever, microfilming has made it possible to re-
e everything to a small volume of microfilm
hments.

Preliminary estimates of the Scientific Research
itute for Labor of the State Committee on Labor
Wages show that equipping planning and design-
organizations with up-to-date technical appli-
es would yield economies of 12 to 20 per cent. This
ns a saving of 120,000 to 220,000 rubles for every
ion rubles spent on planning and designing work.

The technological preparations for production in the machine-building industry require a large number of various technical documents drawn up on the basis of original drafting data: blueprints of the technological process, designing special equipment, fittings, measuring and cutting instruments, calculation of standards for the expenditure of materials, semi-manufactured goods and labor per unit. This entails a great many labor-consuming operations. Rational use of calculating machines for this purpose would considerably reduce the labor and time required for preparing the documents and improve their quality. The principle of preparing documents in a way which would eliminate the necessity of rewriting them and thus considerably reduce the labor entailed in working out the preliminary technological preparations for production also deserves attention.

Mechanization and automation of primary accounting, first of all in industry and eventually in all other branches of the national economy, merits special attention. It is essential to work out a system of primary accounting and reporting suitable for processing by electronic and other technically advanced computing machines and to ensure its application in the national economy. In this connection it is important to develop special calculating devices adapted to the specific features of production. Thus, at the Likhachev Automobile Works, for example, automatic devices have been developed for multi-spindle automatic lathes, gear-milling and wood-working machines, for automatic spring winding, for mold-making machinery, and on the conveyers in foundry shops. Some of these devices have centralized remote control. Their introduction made it possible to reduce the number of accounting clerks and to accelerate both the manufacture of the items and the process of counting them.

The technical equipment at the disposal of administrative and managerial staffs is also on a very low level at the moment. There is still no uniform bookkeeping system and as a result each enterprise and office follows its own system of keeping accounts. Billing and addressing machines which greatly ease clerical work are not used. The technique of arranging and preserving archive materials is still faulty, there are no special racks and card indexes, no modern pneumatic and electrical devices for transporting documents. Nor is there any special furniture for managerial personnel.

If we are to ensure a radical improvement in the mechanization and automation of the labor of designers, technologists, administrative staffs, archivists and other engineering and managerial personnel we must first of all work out designs and ensure quantity production of a large variety of essential machinery, gauges, instruments, devices and other equipment. Work in this direction has already begun.

Within the next few years we must begin the large-scale production of equipment for primary accounting and receipt of primary information, its processing and transmission to distribution centers, namely, various transmission devices and computors, weighing and measuring instruments, telephone, telegraph and photo-telegraph communication, dictaphones and so forth.

The measures taken to increase the output of drafting and designing equipment — drafting apparatus and boards of various design, different appliances, devices and instruments as well as special furniture for designers — are equally important.

The production and use of a variety of highly effective tracing and reproduction equipment will also develop on a large scale in the next few years. This will include photo-printers, electronic printers, rotary presses, apparatus for microfilming, billing and addressing machines and many other types of equipment.

Many of the employees in bookkeeping departments and archives will soon be supplied with highly effective equipment which will considerably facilitate their work: card indexes of various designs, bookkeeping machines, instruments and appliances, and pneumatic and electro-mechanical devices for transporting documents in depositories.

The enterprises, organizations and offices must see to it that they make good use of these time-saving means of mechanization and automation which ease the work of designers, technologists and other engineering, administrative and managerial personnel.

When introducing the new technology into engineering and managerial work it is very important to ensure its integrated application. In material production the path from mechanization of individual processes to integrated mechanization was a long one. Here we must shorten this process considerably.

In tackling the methodological and practical issues in the integrated mechanization of engineering and managerial work we should bear in mind the important directive of the government that exemplary work be organized in several state institutions, planning and designing organizations, as well as in the management of production at experimental complex-mechanized and automated enterprises. Eventually these new methods of work will be extended to other enterprises and organizations.

If the responsibility for mechanization of accounting and statistics rests with the Central Statistical Administration, the preparatory work mechanizing managerial jobs is the responsibilit of the State Committee of the USSR Council of Mi isters on Labor and Wages. The latter has the very important task of working out scientific met ods of managing enterprises and offices, of elaborating methods for determining the technologica and economic efficiency of applying the means of mechanization and automation of engineering, ad ministrative and managerial jobs, of elabroating system of indexes and norms for determining th level of mechanization of managerial work and a number of other important tasks in the organiza tion and mechanization of management of enterprises and offices. This committee is also resp sible for working out the technical assignments a number of machines, instruments and types of equipment designed for mechanization and autom tion of managerial work.

In view of the forthcoming extensive mechaniz tion of accounting and other managerial work it an important state matter to ascertain the effica of mechanization of these duties and to impleme them as soon as possible, thereby releasing a p of the administrative and managerial personnel for work in production. This is especially impo tant because the practice of mechanization of accounting and calculating work has shown that enterprises and organizations do not always release such personnel.

Thus, we get a very diverse picture when com paring the number of accounting personnel with total number of employees in various enterpris or organizations with the same level of account mechanization. Some differences between individual enterprises are possible of course, but h can one explain, for instance, why at the Mytish Engineering Works there is one bookkeeping-accounting worker per 56 employees while at th Podolsk Kalinin Mechanical Plant there is one such worker, including those in the calculating chine installation, per 141 employees. This ca hardly be explained by the specific features of respective enterprises.

The government has instructed the Councils Ministers of the Union Republics, the ministrie and departments of the USSR to specify the red tions in the number of personnel employed in a counting and other administrative and manager jobs at enterprise and organization after the im plementation of mechanization and automation managerial work. Along with this an importan privilege has been established for calculating chine stations and factories which switch to a accounting basis. At present calculating mach rators and mechanics of calculating machine in- llations do not have to register with the financial ncies.

ut apart from the direct saving of manpower, most important effect, even though it cannot be cisely estimated, one which will amount to many ions of rubles, will come from accelerating and roving the quality of planning and designing, m more operational management, from the adop- of more effective decisions as a result of mpt and accurate information on the progress of duction. This will doubtlessly find its reflection ess expenditure of time on mastering the produc- of new items, in savings of labor and materials, mproving the quality of output and all technical economic indices.

vital role in the solution of these government s belongs to the scientific and engineering so- ies. It is their duty to propagate the advanced hods of mechanization and automation of ineering and managerial work. They will have to summon special conferences, issue books, brochures and information bulletins, organize excursions, etc. Every effort must be made to encourage innovators and rationalizers of mechanization of the labor of engineering and managerial staffs.

The economic councils, ministries and departments, enterprises and designing organizations developing technical means for mechanizing and automating engineering and managerial work must firmly overcome the difficulties which may arise in this work and focus the attention of all personnel on the fulfillment of these government tasks.

Footnotes

(1) *Collected Works*, 4th Russian edition, Vol. 33, p. 450.

(2) *ibid.*, p. 451.

(3) *ibid.*, p. 301.

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Voprosy Ekonomiki, No. 9, 1960

RACHEV:

International Session on Questions of ustrial Statistics

der conditions of the existence of two economic ems — the socialist and capitalist systems — the peaceful economic competition between , the comparison of methods and statistical becomes a matter of great importance. One e forms of strengthening international coopera- is the convening of various international confer- s of economists on these questions. This is ested by the participation of Soviet representa- in the work of the conference of European sticians and its working groups.

rly in 1960 a session of the working group on strial statistics took place in Geneva. This was set up to discuss the document on the for holding a World Industrial Census in 1963 n up by the UNO Statistics Bureau and to study lans for carrying out a European census (the ction of data on local units and enterprises, the flow of commodities to the market, etc.). The session was attended by representatives of Austria, Belgium, Britain, Hungary, Greece, Spain, Italy, Luxemburg, the Netherlands, Norway, Rumania, the Soviet Union, the USA, Turkey, the FRG, Finland, France, Czechoslovakia, Sweden, Yugoslavia and Canada.

The session was presided over by Mr. Luther, the Finnish representative. Under the established procedure the Soviet representative N. G. Grachev, who was elected his assistant, will preside at the next session to be held in 1961. The agenda of the session included the following major questions: the formulation of summary instructions for the draft revision of international standard concepts of basic industrial statistics and the draft proposals for a World Program of Basic Industrial Surveys for 1963; drawing up of variants of international standard concepts and the World Program suitable for European conditions; the examination of aspects of the statistics of enterprises pertaining to the above-mentioned tasks.

The discussion of these questions was preceeded by a general discussion subordinated to the main task of the session — to introduce the necessary amendments to the international standard concepts of basic industrial statistics with the aim of evaluating the methods now in use and to improve the comparability of international industrial statistical data. The importance and relevance of this task was not questioned by any of the participants in the session with the exception of Dr. Furst, the FRG representative, who cast doubt on the possibility of comparing the methods and statistical data of various countries. The arguments he used were far-fetched and the examples he cited were not at all typical. All the other participants in the session tried to establish the common features in the methods of calculating the corresponding statistical indices or to define the corrections required to make the concepts and data of industrial statistics in different countries comparable.

The advantages of socialist industrial statistics were convincingly demonstrated at the session both from a methodological and economic point of view. For example, the Soviet Union and other socialist countries have no need to hold special industrial surveys under the 1963 World Program. Because of the system of regular reports and accounts (annual, quarterly, monthly), obligatory for all enterprises and organizations, the USSR has at its disposal complete data on the work of its industry for any year, quarter or month. Many of the basic statistical indices are published in the USSR Central Statistical Administration yearbook *The National Economy of the USSR*. And the number of these indices is growing with every year.

It should be noted that after the Soviet representative reported on the advantages of socialist statistics, Mr. Luther, chairman of the session, said that he envied Soviet economists who have such a well-organized system of state statistics. However, all these advantages not only do not exclude but, on the contrary, only serve to stress the necessity of international comparisons of statistical data. In this respect the work of the session rightly deserves approval: the discussion and elaboration of international standard concepts of industrial statistics at the session helped to solve the problem of comparing statistical data in various countries.

It should be said that the comparison of a number of industrial indices for the various countries does not present any great difficulties. Such indices include: 1) the number of people employed in
industry as a whole and in its separate branches
2) power capacity; 3) the size of enterprises according to the number of employees; 4) the bran
structure of industry; 5) the volume of productio
of the major products in physical terms, and oth
The latter index replaces the index of the volum
production in money terms and has certain adva
tages over it, for example, in comparing the lev
of per capita production of different products in
various countries.

The Soviet representative noted, among other
things, that the data on the production of 92 type
commodities published in the USSR Central Stat
tical Administration yearbook *The National Eco
omy of the USSR in 1958* could serve as a basis
comparing the volumes of production in physica
terms. After discussion of this question the ses
sion noted in one of its recommendations that fo
purposes of international comparison it would b
convenient to have a comparatively short list of
products including approximately from 50 to 10
basic commodities.

The Soviet representative also pointed out tha
the comparison of the levels and dynamics of st
tistical indices within the limits of separate
branches of industry is one of the most importa
directions of international comparison in studyi
the levels of development and the structure of i
dustries in different countries. For example, w
can compare the structure of the industry of dif
ferent countries on the basis of an international
standard industrial classification of all branche
of activity (within the limits of 11 to 51 positio
The session was informed that the Department
Economic Statistics of the USSR Academy of Sc
ences Economics Institute is carrying out rese
in this direction.

Much attention was devoted to a discussion o
production indices used in various countries to
characterize the results of the production activ
of industry. In their reports the delgates of a n
ber of countries (for example, the Netherlands)
mentioned the advantages of the "value added"
dex and tried to contrast it to the gross output
based on the factory method used at present in
viet industrial statistics. The Soviet delegates
made a statement in this connection. He pointe
that the valued added index also includes amort
tion. From the viewpoint of theory this is wro
for amortization is a form of material expendit
and cannot, therefore, be included in value add

In the Soviet Union an annual estimate is ma
of the net output of industry and of the national
economy as a whole. The gross output index in
Soviet industrial statistics is evaluated on the
sis of the factory method as well as other meth

nely: the branch and national economy methods.
ertain branches of industry, for example, in the
ving industry, due to the specific features of this
nch of production the index of the cost of proc-
ing (sewing) is also used as a supplementary
thod.

he gross output index based on the factory meth-
is of great importance for characterizing inter-
nch ties and as a basis for evaluating the net out-
. It can also be used for determining labor
ductivity in separate branches of industry and
estimating labor productivity indices for indus-
in general. The gross output index also reflects
labor expended in the past. This is a very im-
tant matter because the reduction of labor ex-
diture per unit of production is an important fac-
in increasing the social productivity of labor. In
er words, the magnitude of the net output also
nges as a result of the influence of changes in
amount of labor expended in the past per unit of
duction. Soviet statistics also uses physical out-
indices in characterizing the levels and dynam-
of labor productivity in a number of branches
ndustry.

he evaluation of the volume of production is
sely connected with the question of establishing
basic accounting unit (in Soviet statistics — the
c reporting unit). This question aroused a
thy discussion which helped, to a certain ex-
, to bring to light the differences in interpreting
meaning of such a unit in various countries. It
explained to the session what meaning Soviet
strial statistics places on the term — basic
unting unit. However, the session did not adopt
common recommendation for all countries on
question. This matter will be taken up at the
session. The session only outlined several
n characteristics of a basic accounting unit (for
nple, uniformity with respect to the type of
omic activity). The working group also noted
the term "enterprise" defined in the countries
astern Europe on the basis of technological,
omic and administrative characteristics also
esponds to this criterion (feature), and quite
ibly is even more uniform with respect to the
of economic activity than many similar estab-
ments in other countries.

other question was also discussed in connec-
with the concept of a basic accounting unit,
ely — the question of so-called integrated units
bines), the system of their accounting, and the
unting of their output, the number of employees,
Dr. Furst, the FRG representative, tried to
ise this issue as well by thinking up various
icial situations (for example, a bakery which
uces or even resells chocolate!). It was explained to Dr. Furst that Soviet industrial statistics can easily solve even such an artificial problem. If the bakery resells chocolate this does not increase the volume of industrial output. At long last the question of the accounting of the volume of resold commodities, on the discussion of which Dr. Furst insisted, was completely excluded from the recommendations of the session.

The participants in the session displayed great interest in the report of the Soviet representative on the system of recording the output of combines (complex enterprises) used in Soviet industrial statistics. This system lists the number of production units comprising the combine and takes into account several basic indices in each.

In addition to specifying the concept of an enterprise as the main accounting unit, the session also discussed the question of grouping enterprises according to their size. The number of employees was proposed as the basic characteristic of such a grouping. The Rumanian delegate pointed out that at present this characteristic is somewhat outdated from the theoretical point of view, for it minimizes the economic significance of highly mechanized branches and enterprises. In this case the index of power capacity would be more justified from the economic point of view. This opinion was supported by the Soviet representative.

As a result, the participants in the session, without objecting in principle to this proposal, nevertheless recommended for the next few years the use of the index of the number employed as the basic characteristic for the above-mentioned groupings. Up to now this index has been most widely used in the statistics of the majority of countries. This recommendation did not meet any objections.

During the discussion of changes in standard concepts it was proposed to distinguish only 5 groups of enterprises with limits of 5, 10, 20, 50 and 100 employees. In the course of the discussion it was proposed to establish the upper limit at 200 or 250 workers. On the proposal of the Soviet delegate this grouping was expanded to include enterprises with a limit of 200, 500, 1,000 and 5,000 employees, since the grouping of enterprises in the statistical yearbook The National Economy of the USSR contains larger units (500; 501-1,000; 1,001-3,000; 3,001-10,000; over 10,000 employees).

During the discussion on the methods of comparing data on the labor force, attempts were made to place members of producers' cooperatives in Eastern Europe in the same category as private owners in Western Europe. The Soviet representatives declared this to be inadmissible as in the socialist countries there is no distinction in principle between members of producers' cooperatives and employees of state enterprises, because state property and cooperative-collective farm property are two forms of a single type of property, namely — socialist property.

When the methods of comparing production wages were discussed the Soviet representative proposed to distinguish (and not to include) from the data on wages in capitalist countries the sums deducted by employers for social insurance, pension allowances to families, etc. The deducted sums should be compared separately, for example, with the social fund for servicing the working people in the USSR. This proposal was accepted.

In the discussion on comparing the data for power installation capacities it was pointed out that the indices on prime movers not driving electric generators should be optional for the countries of Europe. In Soviet industrial statistics these indices are taken into account. The accounting of these indices is of greater significance for countries with a less developed industry because the abse of capacity indices for mechanical drives in the statistical data would lead to an underestimation the share of these countries in comparisons of p er capacity indices.

Sessions of working groups do not take any decisions which are obligatory for the participatin countries. They only make recommendations. These recommendations, without changing the m ods of computing the indices and the systems of porting existing in different countries, make it p sible to achieve certain improvements and to establish what the basic concepts and methods o industrial statistics in various countries have in common. At the same time these recommendati make it possible to establish the differences in these concepts and methods, to outline the metho of comparing statistical indices and the methods computing them used in different countries.

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